University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Historical Materials from University of Nebraska-Lincoln Extension

Extension

1993

EC93-219-A 1994 Nebraska Swine Report

Follow this and additional works at: http://digitalcommons.unl.edu/extensionhist

"EC93-219-A 1994 Nebraska Swine Report" (1993). *Historical Materials from University of Nebraska-Lincoln Extension*. 4852.
http://digitalcommons.unl.edu/extensionhist/4852

This Article is brought to you for free and open access by the Extension at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Historical Materials from University of Nebraska-Lincoln Extension by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

CYT
S
85
E7
no. 219
Copy 1

University of Nebraska Cooperative Extension EC 93-219-A

1994

NEBRASKA SWINE REPORT

Nebraska Cooperative
Extension Service
Extension circular
Received on: 03-03-94
University of Nebraska,
Lincoln -- Libraries

- Breeding
- Disease Control
- Nutrition
- Economics
- Housing

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

Cooperative Extension Division
Agricultural Research Division
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Kenneth R. Bolen, Director of Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources.

It is the policy of the University of Nebraska-Lincoln Institute of Agriculture and Natural Resources not to discriminate on the basis of sex, age, handicap, race, color, religion, marital status, veteran's status, national or ethnic origin or sexual orientation.

CONTENTS

Effect of Protein Level and Genetic Population on Performance and Carcass Characteristics of Growing-Finishing Pigs 3
The Evaluation of Electromagnetic Scanning on Prediction of Protein and Water in Pork Carcasses 5
The Impact of Orientation During Electromagnetic Scanning on Lean Prediction in Hams 8
Processing Characteristics of Pork from a Fat and a Lean Line of Pigs 9
Determinants of Profit Variability in Feeder Pig Finishing 11
Age at Puberty in Gilts as Affected by Type of Boar Exposure 13
Further Development of a Technique to Improve the Superovulatory Response in Pigs 15
The Effects of Dietary Protein Concentration on Compensatory Growth in Barrows and Gilts 17
Evaluation of a Soybean Meal:Soy Lecithin:Soapstock Mixture for Nursery Pigs 19
Degrees and Diets for Weaned Pigs 22
Meal Patterns of Weanling Pigs Fed Diets Containing Either Spray-Dried Porcine Plasma or Dried Skim Milk 25
Effects of Soy Protein and Carbohydrate Source on Performance of Weanling Pigs 26
Nutrient Recommendations for Pigs in Denmark 28
Selection for Size of Testes Increased Growth Rate But Did Not Affect Ovulation Rate and Puberty of Daughters 30
Selection for Size of Testes Decreased Age at Puberty of Boars 33
Effect of Selecting for Increased Testis Size in Boars on Testis Development and Rates of Sperm Production 36
Breaking the Chain of Swine Dysentery Transmission: Development of a New Diagnostic Test to Identify Carrier Pigs 39
Intestinal Spirochetosis, A Newly Recognized Diarrheal Disease of Growing Pigs 41
Sensory and Nutritive Qualities of Pork Strips Prepared by Three Household Cooking Techniques 42
1993 Swine Enterprise Records 44

Issued January 1994, 6,000

ACKNOWLEDGMENTS

Ag Processing Inc., Omaha, NE
American Cyanamid Co., Wayne, NJ
Cargill-Excel Meats, Inc., Minneapolis, MN
CBP Resources, Greensboro, NC
Eli Lilly and Company, Indianapolis, IN
Fats and Proteins Research Foundation, Fort Meyers Beach, FL
George Cammack, DeWitt, NE
Geo. Hormel Packing Company, Fremont, NE
IBP, Dakota City, NE
Intervet Inc., Millsboro, DE
John Morrell Packing Company, Sioux Falls, SD
John Pennor, Plymouth, NE
National Pork Producers Council, Des Moines, IA
Nebraska Agricultural Research Division, University of Nebraska, Lincoln, NE
Nebraska Farmer, Lincoln, NE
Nebraska Pork Producers Association, Lincoln, NE
Nebraska SPF Accrediting Agency, Lincoln, NE
NutriBasics, Highland, IL
Pig Improvement Company, Inc., Franklin, KY
Pfizer, Inc., Terre Haute, IN
Schering - Plough Animal Health Corp., Kenilworth, NJ
Sioux Preme Packing Co., Sioux Center, IA
SmithKline Beecham Animal Health Products, West Chester, PA
U. S. Meat Animal Research Center, Clay Center, NE
Waldo Farms, DeWitt, NE
Wimmer Meat Products, Inc., West Point, NE

The 1994 Nebraska Swine Report was compiled by Rodger K. Johnson, Professor, Animal Science, Department of Animal Science.

Cover Photo:

Pictured are the staff at the Swine Research Center. Kneeling left to right are: Tom McGargill, Caryl Carstensen, Jane Fessler, and Darryl Barnhill; standing are Matt Anderson, Dan Cheleen, Jeff Perkins, Brian Lynch, and Norman Rohda.

Effect of Protein Level and Genetic Population on Performance and Carcass Characteristics of Growing-Finishing Pigs

Hsin-Yi Chen
Phillip S. Miller
Austin J. Lewis[1]

The production of lean pork has become a priority for the swine industry during the past five years. Increased market premiums for lean carcasses and decreased profit margins for fat have driven the industry toward leaner, more efficient pigs. Production is targeted at raising pigs with improved feed efficiency and increased lean gain. Research has indicated that genetic populations differ in lean gain and that lean gain can be influenced by dietary protein content.

Pigs of different genetic populations may have different nutrient requirements. These differences have been associated primarily with differences in lean growth rate. Although the genetic potential for lean growth rate influences the requirements for all nutrients, the effects on protein requirements are probably the largest and the most economically important. Pigs with high rates of lean growth gain weight faster, utilize feed more efficiently, and produce carcasses with more muscle and less fat. Consequently, they require a higher concentration of dietary protein to achieve their genetic potential for lean growth.

The objective of this study was to determine the protein requirements of two different populations of pigs with different genetic potentials for lean growth. The populations chosen for this study were selected to gain information regarding genetic and nutritional constraints on lean growth in pigs and not specifically to determine the nutrient requirements of these populations. Furthermore, we anticipate that defining the protein (amino acid) requirements of these populations will allow us to further refine future experiments designed to investigate the mechanisms involved in lean and fat deposition in the growing-finishing pig.

Methods

Forty-six Gene Pool gilts (low lean growth potential) and forty-six Hampshire gilts (high lean growth potential) with an initial body weight of 63 lb were used. The Gene Pool is a 14-breed composite population formed from 1962 to 1965 and then closed to outside introductions. Since 1967 it has been selected only for reproductive traits. Therefore, its growth and fat characteristics are typical of pigs of 30 years ago. The Hampshire pigs were obtained from a Nebraska SPF breeder. Ten pigs from each population were randomly selected and slaughtered at the beginning of the study as an initial control group for the evaluation of carcass composition. The remaining 72 pigs, penned individually in an environmentally controlled room, were allotted to six dietary treatments.

The compositions and analyses of the six diets are shown in Table 1. Pigs had ad libitum access to feed and water throughout the entire experimental period. Diets were formulated to contain .65% Ca, .55% P, and 10, 13, 16, 19, 22, and 25% protein, respectively. Pigs were weighed and feed intakes were measured weekly. Average daily gain, average daily feed intake, and feed/gain were determined.

Pigs remained on the experiment until the average body weight of a treatment within each population reached approximately 250 lb, at which time all pigs of that population were removed from the experiment. Gene Pool pigs had been on feed for 16 weeks and Hampshire pigs for 14 weeks. Pigs were slaughtered after a 24-hour fast (during which water was available). After slaughter, carcasses were chilled at 40°F for 24 hours and the following data were obtained: cold carcass weight, longissimus

(Continued on next page)

Table 1. Composition of diets[a]

	Dietary protein concentration, %					
Item	10	13	16	19	22	25
Ingredient, %						
Corn	92.10	84.00	75.65	67.25	59.00	50.80
Soybean meal, 44% CP	5.00	13.25	21.75	30.25	38.65	47.00
Dicalcium phosphate	1.40	1.25	1.05	.90	.70	.55
Limestone	.40	.40	.45	.50	.55	.55
Salt	.30	.30	.30	.30	.30	.30
Trace mineral premix	.10	.10	.10	.10	.10	.10
Vitamin premix	.70	.70	.70	.70	.70	.70
Nutrient composition[b]						
Crude protein, %	9.75	12.53	15.53	18.61	21.33	24.29
Lysine, %	.36	.55	.75	.95	1.16	1.35
Calcium, %	.64	.62	.62	.63	.64	.62
Phosphorus, %	.56	.53	.53	.53	.51	.51
Metabolizable energy, kcal/lb[c]	1,502	1,496	1,491	1,485	1,480	1,475

[a] As-fed basis.
[b] Analyzed composition.
[c] Calculated.

muscle area, and backfat at first rib, tenth rib, last rib, and last lumbar vertebra. Right half carcasses were frozen, finely ground, homogenized, sampled, and analyzed in duplicate for protein, fat, water, and ash. Average daily gain of protein, fat, water, and ash of carcass were calculated.

Results

Growth Performance. Average daily gain, average daily feed intake, and feed/gain data are shown in Table 2. No significant interactions (P>.1) of population with protein level were found. Hampshire pigs grew more rapidly and utilized feed more efficiently during all periods (P<.001) than did Gene Pool pigs. Average daily feed intake during each period was not different for the two populations. Protein level had a significant quadratic effect on average daily gain and feed/gain (P<.05). Pigs fed the 16% CP diet gained the fastest in the first period. During the second period and for the total period, average daily gain was greatest in Gene Pool pigs fed the 13% CP diet and in Hampshire pigs fed the 16% CP diet. Average daily feed intake was not affected by protein level except in the first period (P<.05).

Carcass Traits. Data for carcass traits are summarized in Table 3. No significant interactions (P>.1) of population with protein level were found. There was no population effect on dressing percentage (P>.1). Carcass backfat depths were significantly lower (P<.001) in Hampshire pigs than in Gene Pool pigs. In addition, longissimus muscle area was larger in Hampshire pigs (P<.001). All carcass traits were influenced by protein level (P<.01). Increased levels of protein resulted in decreased dressing percentage (P<.005), whereas backfat depths and longissimus muscle area were improved as protein level increased (P<.005).

Carcass Composition Gain. A population by protein interaction was detected (P<.01) for protein and water gain (Table 4), indicating that the response patterns associated with protein level were different between populations. Accretion rates of protein, water, and ash were higher and fat accretion lower in Hampshire compared to Gene Pool pigs (P<.01). Protein level had effects on accretion rates of all carcass components evaluated (P<.001). There was a quadratic increase in protein, water, and ash accretion rates (P<.001) and a linear decrease in fat accretion rate (P<.001) as dietary protein concentration increased. Protein accretion rate was maximized for Gene Pool pigs fed 13% CP and Hampshire pigs fed 16% CP.

Table 2. Effect of protein level on growth performance of Gene Pool and Hampshire pigs

	Gene Pool						Hampshire					
Item	10%	13%	16%	19%	22%	25%	10%	13%	16%	19%	22%	25%
Week 0 - 8												
ADG, lb[bcd]	1.40	1.65	1.69	1.56	1.58	1.58	1.43	1.73	1.99	1.79	1.80	1.82
ADFI, lb[c]	5.51	5.79	5.41	5.02	5.18	5.25	5.58	5.52	5.81	4.98	5.20	5.25
Feed/Gain[bcd]	3.95	3.51	3.22	3.23	3.30	3.32	3.92	3.17	2.93	2.78	2.91	2.89
Week 8 - Slaughter[a]												
ADG, lb[bd]	1.46	1.81	1.59	1.59	1.51	1.66	1.49	1.95	1.97	1.86	1.91	1.83
ADFI, lb	6.35	7.35	6.75	6.70	6.83	6.86	6.44	6.64	7.47	6.59	7.16	7.16
Feed/Gain[bd]	4.42	4.11	4.26	4.25	4.68	4.15	4.32	3.41	3.80	3.54	3.74	3.95
Week 0 - Slaughter[a]												
ADG, lb[bcd]	1.43	1.73	1.64	1.58	1.55	1.62	1.46	1.83	1.98	1.82	1.84	1.82
ADFI, lb	5.93	6.57	6.08	5.86	6.01	6.05	5.95	6.00	6.52	5.67	6.04	6.07
Feed/Gain[bcd]	4.16	3.81	3.71	3.72	3.93	3.73	4.09	3.27	3.30	3.11	3.27	3.34

[a] Gene Pool pigs were slaughtered at week 16, and Hampshire pigs were slaughtered at week 14.
[b] Main effect of population (P < .001).
[c] Linear effect of protein (P <.05).
[d] Quadratic effect of protein (P < .05).

Table 3. Effect of protein level on carcass characteristics of Gene Pool and Hampshire pigs[a]

	Gene Pool						Hampshire					
Item	10%	13%	16%	19%	22%	25%	10%	13%	16%	19%	22%	25%
Dressing, %[c]	74.51	74.56	74.14	72.68	73.11	73.19	74.65	74.80	74.53	74.05	73.54	73.46
Backfat depth, in												
First rib[bcd]	2.05	1.91	2.02	1.85	1.95	1.91	1.77	1.47	1.31	1.19	1.35	1.37
Last rib[bcd]	1.50	1.29	1.36	1.21	1.32	1.30	1.26	1.12	.94	.86	.92	1.00
Lumbar vertebra[bcd]	1.82	1.58	1.64	1.44	1.56	1.55	1.28	1.01	.96	.90	.81	.86
Average[bcd]	1.79	1.59	1.67	1.50	1.61	1.59	1.44	1.20	1.07	.99	1.03	1.08
Tenth rib[bcd]	1.97	1.59	1.75	1.63	1.86	1.55	1.37	1.08	.83	.87	.83	.87
Longissimus muscle area, in^2[bc]	3.32	4.10	4.15	3.89	3.99	4.35	4.58	5.09	5.58	5.33	5.67	5.64

[a] Final empty-body weight was used as a covariate in the statistical analysis of carcass characteristics. Empty-body weight = (live weight minus gastrointestinal content).
[b] Main effect of population (P < .001).
[c] Linear effect of protein (P < .005).
[d] Quadratic effect of protein (P < .05).

Table 4. Effect of protein level on gain of carcass components of Gene Pool and Hampshire pigs

	Gene Pool						Hampshire					
Item	10%	13%	16%	19%	22%	25%	10%	13%	16%	19%	22%	25%
Protein, lb/day[abcd]	.100	.152	.142	.145	.147	.147	.110	.192	.208	.200	.201	.198
Fat, lb/day[ac]	.625	.661	.611	.542	.527	.534	.592	.573	.566	.453	.464	.477
Water, lb/day[abcd]	.304	.430	.413	.409	.409	.432	.352	.573	.637	.626	.631	.590
Ash, lb/day[ad]	.021	.027	.024	.023	.022	.023	.025	.034	.033	.032	.031	.027

[a] Main effect of population ($P < .01$).
[b] Main effect of population x protein interaction ($P < .01$).
[c] Linear effect of protein ($P < .001$).
[d] Quadratic effect of protein ($P < .001$).

Conclusions

The results from this experiment show differences between populations for growth performance, carcass traits, and tissue accretion rates. The increased average daily gain in Hampshire pigs corresponded to an increased protein accretion rate compared to Gene Pool pigs. Thus, Gene Pool pigs had a lower average daily gain and protein accretion rate than Hampshire pigs even though feed intake was similar for the two populations. This can be explained by reduced feed efficiency in the Gene Pool pigs. Hampshire pigs had a greater magnitude of response to increased dietary protein concentration, indicating that Hampshire pigs have a higher dietary protein requirement.

Protein level had a quadratic effect on performance and protein accretion of carcass. From these data, it appears that average daily gain and protein accretion of the carcass in Gene Pool pigs reached a plateau when the diet contained approximately 13% CP. In contrast, rate of gain and carcass muscling in Hampshire pigs continued to increase up to approximately 16% CP. Although increased protein level resulted in improved backfat depths and longissimus muscle area, these improvements were limited. Therefore, feeding diets containing 16% CP or above to Gene Pool pigs and 19% CP or above to Hampshire pigs would not be economical.

Further research is required to develop a simple, rapid method to determine the protein needs of growing-finishing pigs of different populations so that pork producers can develop more cost-effective feeding programs. Until then, combining knowledge of growth rate, carcass characteristics, and lean percentage is necessary to determine the best feeding strategy.

[1]Hsin-Yi Chen is a graduate student, Phillip S. Miller is an Assistant Professor, and Austin J. Lewis is a Professor, Department of Animal Science.

The Evaluation of Electromagnetic Scanning on Prediction of Protein and Water in Pork Carcasses

N.L. Meseck
B.L. Gwartney
H.Y. Chen
C.R. Calkins
P.S. Miller[1]

Evaluation of protein and water content of pork carcasses is costly and time-consuming for researchers. A rapid, objective evaluation of lean content of pork carcasses would benefit the swine industry.

Recent studies have shown that ToBEC (Total Body Electrical Conductivity) is related to lean tissue content of pork carcasses. An electromagnetic scanner (EMS) measures ToBEC. The EMS chamber is a plastic tube approximately 2 feet in diameter and 7 feet long, around which a copper wire generates a continual and constant, low-level (2.5 MHz) electromagnetic field. A carcass passing through the field will absorb a small portion of this energy, proportional to both the amount of lean tissue (composed primarily of protein and water) and its position within the field. The other components of the carcass, fat and bone, are primarily composed of lipid and ash which have little effect on the field.

A response curve generated by an EMS is usually bell-shaped. As the carcass enters the field it begins to absorb an increasing amount of energy until it reaches the midpoint and then absorbs less energy as it exits. The maximum reading, or highest point on the response curve, is referred to as the peak. This value has been used successfully to predict dissectable lean (no visible fat)

(Continued on next page)

content of carcasses.

The relationships between ToBEC and carcass protein and water are unknown. Therefore, the purpose of this study was to predict protein content of pork carcasses and estimated lean content using current electromagnetic scanning technology.

Materials and Methods

Slaughter and Measurements. Seventy-one pigs were slaughtered at the University of Nebraska Loeffel Meat Laboratory in two replications of a nutrition experiment. Pigs from two distinct populations were fed diets containing a range of 10-15% crude protein. One group came from a single source of Hampshire hogs and the other group was obtained from Nebraska Gene Pool pigs, a composite population which has been closed for 28 generations. Pigs had diverse carcass weights and compositions at slaughter. Since selection of the gene pool pigs was begun in the early 1960s, their inherent level of excess fatness resulted in a distribution of carcass composition that differed from the Hampshire population.

Carcass weight was variable (mean of 173.3, standard deviation of 16.0), but did not differ between the two populations.

Right sides of all carcasses were used in this study. Sides were weighed following slaughter and after a twenty-four hour chill period. Following chilling, longissimus muscle area at the tenth rib, tenth rib 3/4 backfat thickness, last lumbar backfat thickness, first rib backfat thickness, and last rib backfat thickness were measured on each carcass. Carcass length and temperature were also recorded after slaughter and chilling, but were not useful in the analysis because they had low correlations to protein content and estimated lean content of the sides.

Scanning Procedure. Sides were scanned twice after slaughter (hot) and twice after chilling (cold), fat side down with the posterior end of the carcass entering the scanner first. The peaks for both hot scans were averaged for statistical analysis. Cold scan peaks were also averaged. Care was taken to facilitate smooth entry and exit of the side through the scanner.

Proximate analysis. Following cold scanning, sides were wrapped with plastic to prevent moisture loss. Sides were then ground completely and mixed. A homogenous sample was obtained and analyzed for fat, ash, moisture, and protein content. Estimated lean content was calculated as the sum of total carcass protein and moisture. Portions of these carcass components are found in fat and bone, so estimated lean content is higher than actual lean. However, if constant proportions of protein and moisture are found in these non-lean tissues, then the conclusions drawn from the analysis would be unchanged.

Statistical Analysis. Means, standard deviations, correlations, and regression equations were calculated using appropriate statistical methods. The regression equations for weight and percentage of carcass protein and of estimated lean were selected for hot and cold sides based on values of Mallow's Cp statistic, the coefficient of determination (CD), and the residual standard deviation (RSD). Equations selected were those with Cp closest to the number of variables in the model (indicating minimal estimated bias in the equation), maximum CD (the amount of variation explained by the equation) and minimum RSD (standard deviation of the predicted value).

Results and Discussion

Peaks for sides at slaughter (hot) were nearly two times greater than peaks recorded after chilling (cold). Fatness varied substantially among carcasses. Tenth rib fat, for example, had a mean of 1.3 inches and a standard deviation of .5 inch. This variation also existed for percent fat. The mean fat percentage was 39.3%, and the standard deviation was 7.2%. Water and protein comprised over 58 percent of side weight on a hot and cold basis (Table 1).

Correlations of protein and estimated lean content with all other variables were calculated (Table 2). The variables most highly correlated with protein weight and estimated lean weight (protein + moisture) were peaks of hot and cold scans. Variables most highly correlated with percentage protein were peaks, tenth rib backfat thickness, and last lumbar backfat thickness. Estimated lean percentage was most highly correlated with tenth rib backfat thickness and last lumbar fat thickness.

A five-variable equation including hot scan peak, carcass weight, and three carcass backfat measurements accounted for 86.9% of the variation in protein weight and had a RSD of .7 lb. An equation with the same variables accounted for 75.8% of the variation in protein percentage and had an RSD of .88%. The best equations using cold scans included four variables (peak, carcass weight, and first and last rib backfat) and accounted for 87.4 and 76.8% of the variation in protein weight and protein

Table 1. Means and standard deviations for right sides of pork carcasses (n = 71).

Variable	Means	Standard deviation
Hot side weight (lb)	86.4	8.1
Cold side weight (lb)	84.7	7.9
Hot scan peak	95.5	22.7
Cold scan peak	49.5	11.6
Loin eye area (in^2)	4.7	1.0
Tenth rib backfat (in)	1.3	0.5
Last lumbar backfat (in)	1.3	0.4
First rib backfat (in)	1.8	0.4
Last rib backfat (in)	1.2	0.3
Water %	44.1	5.6
Fat %	39.3	7.2
Protein %	14.1	1.7
Hot protein weight[a] (lb)	12.2	1.9
Cold protein weight[b] (lb)	11.9	1.8
Hot estimated lean weight[c] (lb)	50.3	7.6
Cold estimated lean weight[d] (lb)	49.3	7.5
Estimated lean %[e], cold	58.2	7.1
Estimated lean %[f], hot	59.0	7.0

[a]Percentage protein x hot weight.
[b]Percentage protein x cold weight.
[c]Hot weight x (percentage water + percentage protein).
[d]Cold weight x (percentage water + percentage protein).
[e]Protein percentage + moisture percentage.
[f]Protein percentage + moisture percentage, corrected for moisture loss during chilling.

percentage, respectively. The RSD for equations including cold scans were .67 lb for protein weight and .85% for protein percentage (Table 3).

The best equations including hot side scans accounted for 93% of the variation in estimated lean weight and 88% in estimated lean percentage (Table 4). In contrast, the NPPC equation derived to predict lean weight from a hot, ribbed, pork side explained 67% of the variance in estimated lean weight when applied to this population. Fitting an equation that included only the variables in the NPPC equation to this population accounted for more variance and had a lower RSD than direct application of the NPPC equation. Greater variation in estimated lean weight (95%) and percentage (91%) was explained by equations that included scan peaks on the chilled side rather than the warm side. These data indicate that electromagnetic scanning in combination with measures of carcass fatness and weight provides better estimates of lean content than either scans or traditional carcass measures alone.

Conclusions

Prediction equations using peak, weight and carcass fat measures can accurately predict carcass protein and estimated lean content. In the future, equations to predict carcass lean may incorporate electromagnetic scan values. This could facilitate more rapid feedback for producers and researchers and improve procedures to predict lean content of hogs. This may lead to an improved value-based marketing system.

---

[1]N. L. Meseck, B. L. Gwartney, and H. Y. Chen are graduate students, C. R. Calkins is Professor and P. S. Miller is Assistant Professor in the Animal Science Department at the University of Nebraska-Lincoln.

Table 2. Correlation of carcass and scanning variables with protein and estimated lean content.

Variable[a]	Protein weight	Protein %	Estimated lean weight[b]	Estimated lean %[c]
Hot weight (lb)	.63	.06	.59	< .01
Cold weight (lb)	.62	.06	.59	<- .01
Loin eye area (in^2)	.68	.65	.73	.69
First rib backfat (in)	-.33	-.60	-.44	-.72
Last rib backfat (in)	-.24	-.61	-.34	-.73
Tenth rib backfat (in)	-.50	-.74	-.60	-.86
Last lumbar backfat (in)	-.47	-.75	-.55	-.84
Hot peak	.90	.69	.93	.71
Cold peak	.91	.73	.96	.78

[a]Correlations differed from zero (P < .001), except the correlations of hot weight with protein % (P > .6), hot weight with estimated lean % (P > .9), cold weight with protein % (P > .6), cold weight with estimated lean % (P > .9), first rib backfat with protein weight (P <.005), last rib backfat with protein weight (P < .05) and last rib backfat with estimated lean weight (P <.05).
[b]Estimated lean content = weight x (percentage protein + percentage moisture).
[c]Percentage protein + percentage moisture.

Table 3. Prediction of pork carcass protein from measures obtained on hot or chilled sides.

	Protein weight (lb)		Protein %	
Independent variables[a]	CD[b]	RSD[c]	CD	RSD
Hot sides				
Peak, weight, FRF,LRF,LLF	86.9	.70	75.8	.88
Chilled sides				
Peak, weight, FRF, LRF	87.4	.67	76.8	.85

[a]Peak = height of scanning peak; weight = hot or chilled side weight; FRF = first rib backfat thickness; LRF = last rib backfat thickness; LLF = last lumbar backfat thickness.
[b]Coefficient of determination (R^2 x 100).
[c]Residual standard deviation.

Table 4. Prediction of pork carcass estimated lean content from measures obtained on hot or chilled sides.

	Weight[a]		Percentage[b]	
Dependent variables[c]	CD[d]	RSD[e]	CD	RSD
Hot sides				
Peak, weight, TRF, LRF	93.5	2.0	88.1	2.5
NPPC equation[f]	67.2	4.3	—	—
Weight, TRF, LMA	85.7	2.9	—	—
Peak only	86.7	2.8	—	—
Cold scanning				
Peak, weight, LLF	95.5	1.6	91.5	2.1

[a]Weight x (percentage protein + percentage moisture).
[b]Percentage protein + percentage moisture.
[c]Peak = height of scanning peak; weight = hot or chilled side weight; TRF = tenth rib backfat thickness; LRF = last rib backfat thickness; LLF = last lumbar backfat thickness; LMA = longissimus muscle area.
[d]Coefficients of determination (R^2 x 100).
[e]Residual standard deviation.
[f]National Pork Producers Council, taken from Procedures to Evaluate Market Hogs. Third edition. 1991. Includes the variables of hot carcass weight, tenth rib backfat thickness, and longissimus muscle area, applied to this data set.

The Impact of Orientation During Electromagnetic Scanning on Lean Prediction in Hams

N.L. Meseck
B.L. Gwartney
C.R. Calkins
P.S. Miller[1]

An accurate measure of lean content of pork cuts would provide the swine industry with valuable information needed for objective pricing of pork products. Prediction of lean content of cuts has been done with varying degrees of success with optic probes, ruler measurements, and ultrasound readings. However, more accurate measures are still needed.

Recently, the relationship between ToBEC (Total Body Electrical Conductivity) and lean content in meat has been studied. The equipment used to measure ToBEC is an electromagnetic scanner, a cylindrical chamber in which an electrical current generates a continuous and constant, low-level (2.5 MHz) electromagnetic field. A subject passing through the scanner will cause a change in the magnetic field proportional to the amount of lean present. Fat and bone, because of their lower conductivity, have little effect on the field.

The typical response curve is bell-shaped, but may vary slightly depending on the geometric shape of the subject. As a meat cut enters the field it begins to absorb an increasing amount of energy until it reaches the center of the field and then absorbs less energy as it exits. The peak of the response curve is used to predict the total lean of the meat cut scanned and represents a point near the middle of the magnetic field. Area under the response curve may also be used to predict total lean.

In previous research, different orientations of the same cut elicited different peaks on the response curve. For example, a ham scanned in three different orientations would elicit three very different response curves. Therefore, the purpose of this study was to determine which orientation in hams would provide the best prediction of dissected lean content.

Materials and Methods

Measurements. Fifty-eight hams were removed from the left side of chilled pork carcasses and studied in two replications of the experiment. Twenty-five hams were used in the first replication and thirty-three in the second. A six-month interval separated the replications. Ham weight, thickness and length from the shank to the cut surface were recorded. Fat thickness on the cut surface, opposite the aitch bone, was also measured.

Scanning Procedure. Each ham was scanned twice in each of three orientations. Hams oriented in a posterior (POS) fashion entered the electromagnetic field shank first with their fat side down. Dorsally-oriented (DOR) hams entered the scanner with the dorsal side first and fat side down, and hams oriented in the upright position (UPP) entered the scanner with the aitch bone side first and the cut surface down. Hams scanned in the UPP were placed in plastic tubs to prevent them from falling over while passing though the scanner.

Dissection. Following the scanning procedure, each ham was separated into lean (no visible fat), fat and bone components. The weight of each component was recorded.

Statistical Analysis. Means and standard deviations for each variable were calculated, and correlation and regression were used to determine the accuracy of measurements made in each orientation for prediction of lean weight and lean percentage of hams. Scan peaks of hams in each orientation along with weight and fat thickness were used in regression equations to predict composition of hams.

Results

Means of scan peaks from hams in the DOR orientation were slightly higher than hams scanned in the POS position, but scans of hams in the UPP position were two times greater than scans of hams in either the POS or DOR position (Table 1). Ham lean weight was slightly more than one-half total ham weight.

Correlations of lean weight and lean percentage with other variables are in Table 2. Scan peaks were highly correlated with lean weight, and scan peaks and fat thickness were equally correlated with lean percentage. Correlations of scan peaks for each orientation with composition were nearly equal. Total ham weight was highly correlated with lean weight. On the basis of these cor-

Table 1. Ham means and standard deviations (n=58).

Trait	Mean	S.D.
Ham Weight (lb)	19.0	2.1
Fat Thickness (in)	1.0	.3
Ham Length (in)	14.9	1.1
Ham Thickness (in)	5.9	.6
Posterior Peak	20.9	6.1
Dorsal Peak	23.9	6.5
Upright Peak	42.5	11.2
Lean Weight (lb)	11.0	2.0
Lean %	57.4	5.1

Table 2. Correlation coefficients of all hams.

Ham traits[a]	Lean weight	Lean %
Weight	.91	.91
Length	.73	.56
Ham thickness	.29	.01
Fat thickness	-.59	-.78
Posterior peak	.95	.79
Dorsal peak	.96	.77
Upright peak	.95	.78

[a]Correlations differed from zero (P< .001), except the correlation of ham thickness with lean weight (P< .10) and ham thickness with lean % (P> .20).

relations, the variables peak, total ham weight, and fat thickness were chosen to be used in equations to predict composition.

Regression equations including scan peak, total ham weight, and fat thickness were calculated for each orientation. These equations had larger coefficients of determination than equations with peak only or peak in combination with one other variable. Precision of predicting lean weight or lean percentage did not differ among equations with scans for the three orientations (Table 3). Residual standard deviations for each equation for predicting lean weight were identical, and were within .1% of each other for equations to predict lean percentage. Coefficients of determination for the equations differed by only .4 for predicting lean weight and 2.6 for predicting lean percentage.

Table 3. Prediction of lean weight and percentage in hams scanned in three orientations

	Lean weight (lb)		Lean %	
Orientation[a]	CD[b]	RSD[d]	CD	RSD
Posterior	94.7	.5	75.9	2.6
Dorsal	94.6	.5	75.3	2.6
Upright	95.0	.5	77.9	2.5

[a] For each orientation, weight, fat thickness, and peak were used as independent variables.
[b] Coefficient of determination.
[c] Residual standard deviation.

Conclusions

Orientation of hams when scanned did not influence the precision of predicting ham lean content (weight or percentage). Equations that included ham weight, fat thickness, and scan peak for each orientation were most effective for predicting lean weight and lean percentage of hams.

[1]N. L. Meseck and B. L. Gwartney are graduate students, C. R. Calkins is Professor, and P.S. Miller is Assistant Professor in the Animal Science Department at the University of Nebraska-Lincoln.

Processing Characteristics of Pork from a Fat and a Lean Line of Pigs

K.F. Goerl
R.W. Mandigo[1]

Processing characteristics of meat is an important consideration for pork producers, packers and processors. The quality and quantity of lean meat obtained from the carcass depend on many factors; two of which are genetics and feed intake, particularly dietary protein. Genotype and dietary protein intake, together, in part at least determine the efficiency of gain as well as the quality of the final product: ***Meat.***

In response to consumer demands for leaner meat products, producers strive to produce leaner hogs with less fat and more muscle while maintaining or improving feed efficiencies. Because there is greater emphasis now than just a few years ago on producing lean pigs, producers are shifting their breeding programs to use lines that are very lean. In addition, meat quality is important to consumers, and information on meat quality from lean carcasses is needed.

The objective of this study was to quantify the differences between the processing characteristics of meat from pigs of two distinct lines, a lean line and a very fat line, fed six different protein levels (10, 13, 16, 19, 22 and 25%). Carcass composition, carcass measurements, and the processing characteristics of lean color, cooking yields and objective tenderness were evaluated.

Methods

Data were obtained from thirty-five gene pool (GP) pigs reared and managed by the University of Nebraska and thirty-six Hampshire (HAMP) pigs obtained from a Nebraska SPF producer. The GP population is a fourteen-breed composite population developed from 1962 to 1967. It has been closed since then and has been maintained with selection only for reproductive traits. They were used as a baseline, or fat line of pigs, to compare with the leaner Hampshire pigs. All seventy-one pigs were individually penned at random and randomly assigned a diet fed *ad libitum* which contained either 10, 13, 16, 19, 22 or 25% protein. The pigs were fed to market weight (mean=229 lb) and slaughtered at the University of Nebraska-Loeffel Meat Laboratory. Live weight, hot carcass weight and cold carcass weight were recorded. Carcass measurements for this study were obtained from the left sides of the carcasses.

Carcasses were scored for muscling (1=thin and light muscled to 3=thick and heavy muscled), ribbed between the 10th and 11th ribs to measure loin eye area (LEA), and tenth rib fat thickness was measured at a point 3/4 the distance over the loin eye. Average backfat thickness was calculated from measurements taken at the first rib, last rib and last lumbar vertebra. Percent muscle was calculated using the formula contained in *Procedures to Evaluate Market Hogs* by the National Pork Producers Council.

Carcasses were fabricated by standard cutting procedures. Hams were dissected into lean, fat, bone and skin, and ham lean yields were calculated. Loins

(Continued on next page)

were cut into 1-inch chops and the chops located at the 9th and 12th ribs and the 1st lumbar vertebra were analyzed for Hunter "L", "a", "b" color, cooking yields and Warner-Bratzler shear force to evaluate tenderness.

Hunter "L", "a", "b" color measurements use light reflectance to give numerical scores for lightness "L" (where 100=white, 0=black), redness "a" and yellowness "b" (higher values=greater red and yellow color). Hunter "L", "a", "b" values were obtained on the raw chops. Three chops were cooked to 158°F internal temperature then cooled to room temperature and cooking yields were calculated. After cooling, 1/2-inch cores were removed from the *Longissimus* muscle, parallel to the muscle fibers and evaluated for objective tenderness using a Warner-Bratzler shear force apparatus on the Instron Universal Testing Machine.

Results

Means for all traits differed between populations (P<.01), (Tables 1 and 2). Hampshire pigs were leaner, had larger LEA, improved color scores, better cooking yields and lower peak force and total energy to shear values than GP pigs.

Ham lean yields, or percent muscle in the ham, increased linearly (P<.01) as dietary protein level increased (Table 1). A linear response (P<.01) was noted for percent muscle in the carcass. Percent muscle increased the most in pigs fed between 10 and 13% dietary protein and increased more slowly with higher protein levels. For LEA, a significant (P<.01) cubic response occurred. The LEA increased with increasing levels of dietary protein up to 16%, but did not change much with higher protein levels. There was a significant (P<.05) decrease in average backfat thickness between pigs fed 16% dietary protein or less, and those fed 19% dietary protein.

The *Longissimus* muscles of the Hampshire pigs were lighter (P<.01) in color than those of the GP pigs, and there was a linear (P<.05) decrease in lightness as protein level increased (Table 2). There was a greater (P<.05) degree of red color (Hunter "a" values) in the *Longissimus* muscles of Hampshire pigs, and there was a linear decrease in redness of muscles as protein in the diet increased. There was a linear (P<.05) decrease in degree of yellowness (Hunter 'b' values) in *Longissimus* muscles of pigs fed increasing levels of protein.

There was no effect of protein on cooking yields of chops. Cooking yields of chops differed between Hampshire pigs and GP pigs (P<.01), chops from Hampshire pigs had greater cooking loss.

Shear force was greater (P<.01) and more total energy was required to shear samples of chops from GP pigs than Hampshire pigs. There was a quadratic (P<.05) effect of protein on peak force and total energy to shear samples of chops. As protein level increased, so did peak force and total energy to shear the samples, but the rate of increase declined so maximum values occurred at the 22% protein level.

Conclusions

Pigs from a fat and lean line differed for carcass traits, muscling, cooking yields, tenderness and lean color. Hampshires were superior to the GP pigs for amount of lean tissue produced, color of *Longissimus* muscle, and objective tenderness. The level of dietary protein did not affect carcass traits as much as line of pig differences, although differences in muscling, backfat, lean color, and tenderness due to dietary protein were found. The GP pigs produced chops which had higher cooking yields than the Hampshire pigs. In contrast, the Hampshire pigs produced chops which were lighter, more red and more yellow in color than GP chops. These line and protein feeding differences may play an important role in the ability of processors to merchandize and manufacture pork into consumer products.

---

[1]K.F. Goerl, is a graduate student; R.W. Mandigo is Professor of Animal Science at the University of Nebraska-Lincoln.

Table 1. Effect of Line of Pigs and Protein Level on Carcass Traits.

	PIG LINE[a]		PROTEIN LEVEL (%)						
TRAIT	HAMP	GP	10	13	16	19	22	25	RESPONSE[b]
Ham Lean Yield(%)	56.26	51.92	50.56	52.33	54.34	55.44	55.85	56.16	*
	(.84)	(.82)	(1.43)	(1.43)	(1.43)	(1.43)	(1.50)	(1.43)	
Percent Muscle	49.24	38.16	39.51	43.19	44.28	44.86	44.42	45.94	*
	(.67)	(.69)	(1.17)	(1.17)	(1.17)	(1.17)	(1.23)	(1.17)	
LEA (in^2)	5.28	3.97	3.68	4.68	5.01	4.61	4.84	4.94	***
	(.11)	(.12)	(.20)	(.20)	(.20)	(.20)	(.21)	(.20)	
Avg Backfat (in)	1.12	1.63	1.46	1.47	1.45	1.25	1.31	1.33	*
	(.03)	(.03)	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	
Muscle Score	2.18	1.63	1.67	1.96	1.96	1.79	1.92	2.13	NS
	(.07)	(.07)	(.12)	(.12)	(.12)	(.12)	(.12)	(.12)	

[a]Means for each trait differed between pig lines (P<.01).
[b]Response due to protein level; *=linear response (P<.05), ***=cubic response (P<.05)
NS=no significant response (P<.05)
Values in parentheses are standard errors of the means (SEM).

Table 2. Effect of Line of Pigs and Protein Level on Pork Chop Characteristics.

	PIG LINE[a]		PROTEIN LEVEL (%)						
CHARACTERISTIC	HAMP	GP	10	13	16	19	22	25	RESPONSE[b]
Hunter Color "L"	52.17	46.58	51.03	51.07	49.03	48.21	48.51	48.39	*
	(.61)	(.62)	(1.05)	(1.05)	(1.05)	(1.05)	(1.10)	(1.05)	
Hunter Color "a"	14.55	12.88	15.52	13.85	14.45	12.67	12.63	13.17	*
	(.31)	(.31)	(.53)	(.53)	(.53)	(.53)	(.56)	(.53)	
Hunter Color "b"	4.97	3.99	5.17	4.73	4.60	4.02	4.13	4.23	*
	(.12)	(.13)	(.22)	(.22)	(.22)	(.22)	(.23)	(.22)	
Cook Yield (%)	71.02	74.28	71.89	73.64	72.69	72.86	71.69	73.16	NS
	(.42)	(.43)	(.72)	(.72)	(.72)	(.72)	(.76)	(.72)	
Peak Force (N)	30.78	35.01	29.19	32.19	33.09	35.38	35.83	31.69	**
	(.83)	(.85)	(1.44)	(1.44)	(1.44)	(1.44)	(1.51)	(1.44)	
Total Energy (J)	.272	.307	.259	.286	.284	.310	.314	.281	**
	(.01)	(.01)	(.13)	(.13)	(.13)	(.13)	(.13)	(.13)	

[a]Means for each trait differed between pig lines (P<.01).
[b]Response due to protein; *=linear response (P<.05), **=quadratic response (P<.05), NS=no significant response (P<.05).
Values in parentheses are standard errors of the means (SEM).

Determinants of Profit Variability in Feeder Pig Finishing

Timothy A. Powell
Debra L. Hansen[1]

Profitability is the lifeblood of a business. An ongoing concern for the swine producer is the profitability and variation in profitability of the swine operation. Swine enterprise record systems (e.g., Iowa Swine enterprise Record System and Nebraska Swine Enterprise Records and Analysis Program) help the producer analyze the economic performance of the enterprise. Individual operation performance can be monitored using group comparisons, but the areas most relevant to bottom-line profitability may not be revealed through a group comparison.

The revenue and cost factors that generate profit were investigated using Midwest data. The data used in this research consisted of feeder pig finishing enterprise data for 1988, 1989, and 1990 from the Iowa Swine Enterprise Records Program and the Nebraska Swine Enterprise Record and Analysis Program. The pooled data provided 41 observations for 1988, 50 for 1989, and 68 for 1990. These programs are similar, with the Nebraska system providing summary data consistent with the Iowa records.

Methods

Profit is a function of income and costs. In this study profit per hundredweight of pork produced is defined as:

Profit (PFT)=Average Market Price (AVEPRC)
- Feeder Pig Cost (FEEDER)
- Feed Cost (FEED)
- Labor Cost (LABOR)
- Utilities Cost (UTIL)
- Veterinary and Medicine Cost (VET)
- Miscellaneous Cost (MISC)
- Depreciation, Taxes, and Insurance Cost (DEP,TAX&INS)
- Interest on Fixed Capital (FIXINT)
- Operating Interest (OPINT),

where all income and costs are expressed per hundredweight of pork produced.

The average market price is the weighted average of all pigs sold. The feeder pig cost is the cost of the feeder pigs purchased. The feed cost is the total cost of feed fed per hundredweight of pork produced. Labor cost includes hired labor and a charge for all family labor used in the swine enterprise.

Utility cost includes fuel, electricity, and telephone. Veterinary and medicine cost includes all veterinary charges and medications not included in the

(Continued on next page)

feed. Miscellaneous costs include all other operating costs (e.g., supplies, heat lamps, bedding, repairs, marketing expenses, etc.).

Depreciation, taxes, and insurance includes an estimate of the depreciation, property taxes, and insurance on all of the swine enterprise facilities and equipment. Interest on fixed capital is an annual capital charge against the market value of the swine enterprise facilities and equipment. Operating interest is based on the average operating capital required times an annual rate.

Results

The mean profit varied from a loss of $1.42 per hundredweight of pork produced in 1988 to a profit of $8.04 for 1990. Profit varied widely in the feeder pig finishing enterprises even over a relatively short time period. Table 1 shows the mean values of all variables for 1988, 1989, and 1990.

Table 1. Mean Values of Profit, Revenue, and Costs for 1988, 1989, and 1990.

	1988	1989	1990
Variable	$/cwt	$/cwt	$/cwt
PFT	-1.42	4.07	8.04
AVEPRC	44.14	45.26	53.99
FEEDER	12.43	8.77	13.17
FEED	23.94	23.74	22.67
LABOR	2.28	2.23	2.56
UTIL	.55	.54	.69
VET	.55	.60	.62
MISC	1.80	1.61	2.06
DEP,TAX&INS	1.70	1.34	1.46
FIXINT	.71	.72	1.05
OPINT	1.60	1.57	1.69

PFT is the profit per hundredweight produced.
AVEPRC is the average market price per hundredweight sold.
FEEDER is cost for purchase of feeder pigs.
FEED is the total feed cost per hundredweight produced.
LABOR is the total labor cost per hundredweight produced.
UTIL is the total utility cost per hundredweight produced.
VET is the veterinary expense per hundredweight produced.
MISC is all other operating costs per hundredweight produced.
DEP,TAX&INS is the depreciation, property taxes, and insurance per hundredweight produced.
FIXINT is the interest charged for capital assets per hundredweight produced.
OPINT is the operating interest cost per hundredweight produced.

The variation in revenues and costs and how they relate to profit was used to measure the importance of factors to bottom-line profitability. This was done by taking the variance of one factor and dividing it by the sum of the variance of all the factors, e.g., variance of AVEPRC divided by (variance of AVEPRC + ... + variance of OPINT). This was done for all factors. This method gives a measure of the relative variance of each factor compared to the whole. This relative measure of variance will sum to one by definition. Table 2 shows the result of this analysis. Three variables stand out; they are the average market price (AVEPRC), feeder pig cost (FEEDER), and feed cost (FEED).

The feeder pig cost affected the variation in profit the most during each of the three years. It accounted for over one-quarter (.275) of the variation in profit for 1988, over one-third (.343) in 1989, and over one-half (.507) in 1990. Feed cost had the next largest effect on profit variability. It accounted for about one-quarter of the variation in profit for 1988 and 1989, .244 and .260, respectively. For 1990, feed cost had the third largest effect on profit variation, accounting for almost one-eighth (.123) of the total variation. The average market price was the last variable to affect significantly the variation in profit for all three years investigated with one-tenth (.100), over one-eighth (.129), and almost one-quarter (.230) of the total variation for 1988, 1989, and 1990, respectively.

Two additional variables were significant for the year 1988. They were miscellaneous cost (MISC) which accounted for over one-tenth (.106) of total variation and depreciation, taxes, and insurance (DEP,TAX,&INS) which accounted for one-eighth (.132) of the total variation. All other variables had a relatively small effect on profit variability for the three years investigated.

Feed cost per hundredweight of pork produced equals the quantity of feed fed times feed price. Both factors can have a significant impact on total feed cost so further analysis was undertaken.

Table 3 presents the results of the procedure that decomposed variance of feed cost. The feed price (FEEDPRICE) had a slightly larger effect on total feed cost for 1988 and 1989 (.556 and .554, respectively), whereas feed quantity (FEEDQUANT) had the largest effect in 1990 (.540). In general, both feed price

Table 2. Decomposition of Profit Variance into Revenue and Cost Variables for 1988, 1989, and 1990.

	Relative Variance		
Variables	1988	1989	1990
AVEPRC	.100	.129	.230
FEEDER	.275	.343	.507
FEED	.244	.260	.123
LABOR	.062	.054	.039
UTIL	.007	.009	.006
VET	.017	.018	.005
MISC	.106	.064	.042
DEP,TAX&INS	.132	.084	.022
FIXINT	.043	.028	.019
OPINT	.013	.011	.007
Total Variance	1.000	1.000	1.000

AVEPRC is the average market price per hundredweight sold.
FEEDER is cost for purchase of feeder pigs.
FEED is the total feed cost per hundredweight produced.
LABOR is the total labor cost per hundredweight produced.
UTIL is the total utility cost per hundredweight produced.
VET is the veterinary expense per hundredweight produced.
MISC is all other operating costs per hundredweight produced.
DEP,TAX&INS is the depreciation, property taxes, and insurance per hundredweight produced.
FIXINT is the interest charged for capital assets per hundredweight produced.
OPINT is the operating interest cost per hundredweight produced.

Table 3. Decomposition of Feed Cost Variance into Quantity and Price Variables for 1988, 1989, and 1990.

	Relative Variance		
Variables	1988	1989	1990
FEEDQUANT	.434	.446	.540
FEEDPRICE	.566	.554	.460
Total Variance	1.000	1.000	1.000

FEEDQUANT is the total hundredweight of feed fed per hundredweight produced.
FEEDPRICE is the average feed cost per hundredweight fed.

and quantity fed have a relatively equal effect on the feed cost per hundredweight of pork produced.

Summary and Conclusions

This paper focuses on the profitability and variation in profitability of feeder pig finishing operations. Data were provided by swine record system participants in Iowa and Nebraska. Factors considered for feeder pig finishing profitability included the market price received for the finished pig; the costs of feeder pigs, labor, utilities, veterinary and medicine, miscellaneous items, depreciation, taxes, and insurance; and interest on fixed capital and operating expenses. The mean profit varied considerably during the study period, suggesting that feeder pig finishing operations are susceptible to changing market conditions.

Three factors accounted for the majority of variation in profits for the years investigated. They were feeder pig cost, feed cost, and average market price. The feed cost was equally affected by the quantity fed and the feed price.

Operators of feeder pig finishing enterprises need to be concerned about revenue and costs. The price they receive for the market pig is critical to revenue. Feeder pig purchases and feed cost per pound of gain are the crucial cost factors. The quantity of feed fed and the cost of the feed are equally important to the total feed bill. Feeder pig finishing operators need to be skilled in marketing. They also need to minimize feed cost per pound of gain and feeder pig purchase costs to expand their profit margin.

---

[1]Timothy A. Powell, Assistant Professor, Department of Agricultural Economics, located at the Northeast Research and Extension Center, Concord, Nebraska. Debra L. Hansen is a former Research Technician, Northeast Research and Extension Center.

Age at Puberty in Gilts as Affected by Type of Boar Exposure

Dwane R. Zimmerman
Tom McGargill
Norman Rohda
Matt Anderson
Steve Christian[1]

Replacement gilts should be managed to express puberty (first estrus and ovulation) at an early age to insure they regularly express estrus once they enter the breeding pool and to optimize their reproductive potential (ovulation rate and litter size) at breeding.

Boar exposure is essential in any successful reproductive management program for developing gilts. Nebraska and British studies demonstrated nearly 25 years ago that providing developing gilts with once daily physical contact with mature boars hastened puberty. But the question of the type or intensity of boar exposure (BE) required to elicit maximal pubertal responses in gilts has only recently been actively investigated. These data are critical when adapting the use of boar exposure to stimulate puberty in gilts under different management systems or designing gilt development and breeding facilities to achieve the full benefits of the boar effect.

Studies of this problem have followed two lines of investigation. First, when direct physical contact with boars is provided, what duration (time period) and frequency (daily, every other day, twice weekly, etc.) of BE are required to elicit maximal pubertal responses in gilts. To summarize from a recent article published in the Nebraska Swine Report (Zimmerman et al., 1991), five minutes of daily contact with mature boars induces comparable early pubertal responses to longer periods (15 or 30 minutes) of BE provided gilts have adequate opportunity for physical contact with the boars. When BE is applied to gilts in advanced stages of sexual maturation or nearing the age at which puberty is typically expressed for the particular genetic stock and management system the gilts are under, once daily boar exposure is a more effective stimulus than alternate-day BE (Nebraska study) or BE on 5 or 2 successive days of the week (Australian study) for triggering a rapid pubertal response in gilts.

The second question concerns what type of boar exposure is required to induce the maximal pubertal response in gilts. Australian researchers have reported recently that direct physical contact with the boar is necessary and is a more effective stimulus than fence-line contact or providing contact with a caged boar when gilts are limited to approximately 30 minutes of BE each day (Table 1). From this and related studies, Australian researchers concluded that direct physical contact between the boar and gilts (especially nose-to-nose interactions initiated by the gilts) was necessary to allow the transfer of the pheromones (16-androstene released from submaxillary saliva glands of the boar) involved in stimulation of puberty in gilts. The wire mesh pen divider that separated the gilts and the boar on the fence-line BE

(Continued on next page)

Table 1. Effect of type of boar exposure (BE) on pubertal response in gilts

Type of BE[2]	Pubertal response, %[3]
None (isolated from boars)	21
Fence-line contact	38
Caged boar	50
Full boar	80

[1]From Pearce, G.P. and A.M. Patterson. 1992. Anim. Reprod. Sci. 27:209.
[2]Gilts received various BE treatments for 30 min each day starting at approximately 170 d of age.
[3]Percent of gilts expressing puberty within one month after initiation of various treatments.

treatment contained only 2-inch square openings and may have prevented direct nose-to-nose contact. Alternatively, boars that did not have the opportunity to interact directly with gilts (both fence-line and caged BE) may have been less aroused and released less pheromone than boars allowed to interact with the gilts.

In previous research at Nebraska, in contrast to the findings of the Australian researchers, no difference in age at puberty was observed between gilts provided once-daily (10-15 min) physical contact with mature boars and gilts that received continuous fence-line contact with mature boars. However, differences in the methods used in these studies may have contributed to the different results.

The Nebraska experiments that evaluated fence-line contact maintained 3 or 4 boars in continuous contact with gilts in adjacent pens. Pen dividers consisted of vertical bars with adequate spacing to allow nose-to-nose contact between the boars and gilts. In all likelihood, gilts provided fence-line boar exposure in our experiments received greater pheromonal stimulation than the gilts in the Australian experiments.

To clarify the relative effectiveness of physical and fence-line contact with boars, the present experiment was conducted with 104 gene pool gilts maintained in confinement at the University of Nebraska-Lincoln's Agricultural Research and Development Center Swine Unit. Gilts were randomly assigned within genetic line and litter to four treatments:

1) No boar exposure, NBE.
2) Daily physical contact with mature boars for 10 minutes each day, DBE.
3) Continuous fence-line contact with mature boars (3 boars adjacent to each pen of gilts), FBE.
4) Continuous physical contact with boars (1 mature boar maintained in each pen of 7 or 8 gilts), PBE. Boar exposure was initiated at 168 d of age and continued until termination of the experiment at 212 d of age.

Results of the experiment are summarized in Table 2.

More gilts provided BE, regardless of type, expressed puberty by termination of the experiment than NBE gilts. Physical BE and fence-line BE induced comparable pubertal responses and mean ages at puberty under the conditions of this experiment. And, both of the continuous BE treatments were more stimulatory to puberty than 10 minutes of daily BE as assessed by both percent pubertal response ($P < .05$) and mean age at puberty ($P < .05$). The difference in mean age at puberty between DBE and NBE gilts was smaller than observed in past experiments. The reduced effectiveness of the DBE treatment compared to findings of earlier studies may be related to the earlier termination date and/or the advanced age of gilts at initiation of treatment. The 12 gilts on the NBE treatment that were still prepubertal at termination were assigned a pubertal date corresponding to the day after termination of the experiment. Mean age at puberty would have been much higher for the NBE treatment had these gilts been allowed to express puberty on an individual basis. Also, when gilts are stimulated with boars near the time they start attaining puberty on their own without receiving BE, it is more difficult to demonstrate a large difference in mean age at puberty.

Table 2. Effect of type of boar exposure (BE) on pubertal response in gilts.

Type of BE[1]	Pubertal response, %[2]	Mean age at puberty, d[3]
NBE	57^{a}	199^{a}
DBE	82^{b}	189^{b}
FBE	96^{c}	180^{c}
PBE	93^{c}	179^{c}
		$^{ab}P < .05$
	$^{ab}P < .01$	$^{ac}P < .01$
	$^{bc}P < .05$	$^{bc}P < .05$

[1]NBE, no boar exposure; DBE, daily boar exposure; FBE, fence-line boar exposure; PBE, physical boar exposure.
[2]Percent of gilts verified to be prepubertal at initiation of experiment (168 d of age) that had expressed pubertal estrus by termination of the experiment at 212 d of age.
[3]Data from prepubertal gilts are included. They were assigned a pubertal date of 6/10 and 6/17 (day after termination) for Reps 1 and 2 respectively, for purposes of statistical analysis. Means with different superscripts differ.

The results of the present experiment failed to confirm the Australian data showing that physical contact with boars is required to achieve the maximal pubertal response in gilts. However, the Australian findings were observed under conditions of limited (30 min) BE rather than the conditions of continuous BE provided in this experiment. Evaluations in the same experiment, of the effects of physical BE vs fence-line BE under conditions of both continuous and limited contact with boars is needed to answer this question with certainty.

---

[1]Dwane R. Zimmerman is Professor of Animal Science, Tom McGargill and Norman Rhoda are Research Technicians, Matt Anderson is Manager at the ARDC Swine Unit, and Steve Christian is Research Technician in the Animal Science Department.

Further Development of a Technique to Improve the Superovulatory Response in Pigs

Dwane R. Zimmerman
Laurie Grammer[1]

Techniques or approaches that increase ovulation rate should, theoretically, increase litter size at birth because ovulation rate (number of ova or eggs released at ovulation) sets the upper limit for litter size and is an important determinant of litter size. Superovulation (injecting additional gonadotropic hormones into the gilt or sow to stimulate recruitment, maturation and ovulation of greater numbers of follicles on the ovaries) is a technique used to increase litter size in pigs, but is of limited value for numerous reasons.

The gonadotropin used most commonly to induce superovulation in pigs is pregnant mare serum gonadotropin (PMSG). This particular gonadotropic (gonad-stimulating) hormone preparation is readily available, can be administered as a single injection because of the extended period it remains in circulation before being metabolized (long half-life) and is effective at stimulating large numbers of follicles to develop and ovulate in association with natural estrus. Treatment with PMSG typically involves a single injection on day 14 or 15 of the estrous cycle or on the day of weaning in sows. Increased numbers of fertilized ova and early embryos result when PMSG is administered in the proper dose (1000 to 1500 IU). However, increased numbers of abnormal ova and degenerating embryos and increased prenatal mortality cause only limited improvement in litter size at birth. Additionally, administration of even the most optimal doses of PMSG achieve highly variable ovulatory responses (from no increase to several fold increases compared to natural ovulation rate) among individual females and induce abnormal follicular development on the ovaries.

Recent evidence suggests that the prolonged half life of PMSG may be a disadvantage. The two gonadotropin activities (FSH, follicle stimulating hormone and LH, luteinizing hormone) contained in PMSG may continue to recruit new follicles over an extended period, stimulate follicles that have begun atresia (natural degeneration) and result in a population of follicles that are heterogeneous or out of synchrony with one another. Most of the follicles are able to ovulate in response to the preovulatory surge of LH released near onset of estrus. However, a substantial number of the follicles fail to ovulate and are retained as large follicles or develop into cystic follicles and continue to produce high concentrations of estrogens during the post-ovulatory period when estrogen concentrations are normally declining to low levels. The ovulatory process is also extended and results in variable development of the corpora lutea (source of progesterone, the hormone needed for maintenance of pregnancy) and asynchronous embryo development and implantation.

Ohio researchers have reported that pig embryos resulting from ova released from later ovulating follicles are out of synchrony with their litter mates and the oviductal and uterine environments they occupy. As a result, they have reduced likelihood of survival. They found that destruction of the final 2 to 4 follicles remaining at the end of the ovulatory process eliminated the 1 to 2 mm embryos and reduced the number of 3 to 5 mm spherical embryos present at day 11 of pregnancy. These are the embryos that are lost during early gestation.

Based on this information, we attempted to develop a superovulation technique at the University of Nebraska that used a different gonadotropin preparation (FSH-P, porcine pituitary gonadotropin with major FSH activity, Schering Plough Animal Health) and to administer the gonadotropin in 6 or 9 injections over 2 or 3 days starting 28 h after an injection of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$, Lutalyse). Lutalyse was given on day 12 or 13 of the estrous cycle to induce luteolysis (cause regression of the corpora lutea, CL) and thereby synchronize initiation of the follicular phase to the same day in all gilts. Partial results from this study using the 10 A.U. dose of FSH-P are presented in Table 1. Complete results were presented previously in the Nebraska Swine Report (Knox and Zimmerman, 1993). To summarize, the FSH-P treatment regimen induced extremely high ovulation rate and produced larger litters of more uniform embryos than the PMSG treatment. But many problems were observed. The dose of 10 A.U. of FSH-P was too high. Excessive ovulations and increased incidence of abnormal follicles (retention of large and development of cystic follicles) were induced compared to control gilts. Another problem was that a substantial percentage of FSH-P treated gilts failed to regress their CL after $PGF_{2\alpha}$ administration. This may have resulted because the interval between induced luteolysis and first FSH-P injection (28 h) was too short and LH contamination in FSH-P was sufficient to reverse the luteolytic effect of $PGF_{2\alpha}$.

(Continued on next page)

These problems called for modification and further evaluation of this approach to superovulation.

The present experiment was designed to evaluate the effects of lower doses and a reduced frequency of injection of FSH-P on ovulation rate and development and retention of large and cystic follicles after ovulation. Gene pool gilts (n=24) were assigned at random to receive a total dose of either 5 or 7.5 A.U. of FSH-P administered in either 6 injections at 8 h intervals (FSH-P 6X) or 4 injections at 12 h intervals (FSH-P 4X) over 2 days starting at 36 h rather than 28 h after $PGF_{2\alpha}$ (Lutalyse) administration on day 12 (5 PM) of the estrous cycle. Ovaries were recovered and evaluated 3 to 5 days after first detection of estrus (checked twice daily). Four gilts (1/TRT) were deleted from the analysis because they failed to ovulate or failed to show superovulation responses. The results are summarized in Table 2.

Dose of FSH-P, but not frequency of FSH-P administration, affected the ovulation rate response. Gilts treated with 7.5 A.U. of FSH-P had higher (P<.05) ovulation rates than gilts treated with 5 A.U. of FSH-P. Overall, the frequencies of gilts retaining large (7 to 12 mm) or cystic (>13 mm) follicles after ovulation (5/20 gilts with large follicles and 6/20 gilts with cystic follicles) and mean numbers of large and cystic follicles were relatively low (Table 2). Except for one gilt with 8 cystic follicles on the FSH-P/7.5 A.U./6X treatment, only 1 or 2 large or cystic follicles were observed on the ovaries of each gilt having these structures. The 7.5 A.U. dose of FSH-P tended to cause a higher incidence of abnormal follicle development than the 5 A.U. dose of FSH-P but both the 5 AU and 7.5 AU doses appeared to reduce incidence of large and cystic follicle compared to the 10 A.U dose of FSH-P evaluated earlier (Table 1). Two gilts on experiment (5 A.U. dose of FSH-P) failed to ovulate; one of these gilts had functional CL and represents the only gilt on the experiment that failed to regress their CL in response to $PGF_{2\alpha}$. This represents a major improvement over the incidence of CL maintenance observed in the previous study when the first injection of FSH-P was given 28 h after $PGF_{2\alpha}$ treatment.

The results of this experiment suggest that 7.5 A.U. of FSH-P administered in four equal doses over 2 days, starting 36 h after induced luteolysis on d 12 of the estrous cycle, has potential for inducing superovulation with minimal adverse side effects. However, replication with additional animals is needed to establish with greater reliability the level of ovulation response and frequency of abnormal follicle development that are to be expected with this treatment regimen. The consequences of this treatment regimen to embryonic development and survival remain to be determined in future experiments.

Table 1. Effect of FSH-P and PMSG on mean (± SE) ovulation rate, numbers of cystic and large follicles, recovery of embryos (%), numbers of embryos and variation (SD) in embryo size on d 10 of pregnancy.

				Embryo			
TRT[1]	OR[2]	Cyst[2]	LRG[2]	R[3]	N[4]	Size[5]	SD[5]
Cont.	13.3 ± 4^{a}	3.0 ± 3	0.0 ± 0	76	10.1 ± 2^{a}	$1.8 \pm .1$	$.49 \pm .11^{a}$
PMSG	35.7 ± 4^{b}	7.6 ± 2	$1.8 \pm .8$	43	15.5 ± 2^{b}	$2.4 \pm .1$	$.92 \pm .12^{b}$
FSH-P	56.3 ± 4^{c}	6.9 ± 2	$3.3 \pm .9$	36	20.1 ± 3^{b}	$2.3 \pm .1$	$.72 \pm .12^{a}$
	$^{ab}P < .05$						
	$^{ac}P < .001$						
	$^{bc}P < .05$				$P < .001$		$P < .05$

[abc]Values in same column with different superscripts differ by probability values given underneath each column.
[1]Control, untreated; PMSG, 1200 IU given i.m. on d 13 (9 p.m.); FSH-P, 10 AU divided into 6 i.m. injections every 8 h beginning on d 13 (9 p.m.).
[2]OR (ovulation rate); Cyst (cystic follicles), LRG (large follicles) determined from gilts expressing each characteristic.
[3]R, embryo recovery = (no. embryos/OR) x 100, averaged over all litters/TRT.
[4]N, number of embryos determined from gilts with normal d 9 or d 10 embryos (Control, n = 18; PMSG, n = 17; FSH-P, n = 13).
[5]Size, diameter in mm; SD, mean of litter standard deviation for embryo diameter, mm.

Table 2. Effect of dose and frequency of administration of FSH-P on mean numbers of corpora lutea (CL), large (7 - 12 mm) and cystic (> 13 mm) follicles.

FSH-P[1] Dose, AU	Inj/day	No. CL	No. Large Follicles	No. Cystic Follicles
5	2	21.0	.33	0
		21.1		
	3	21.2	0	.5
7.5	2	37.0	.50	.33
		34.2*		
	3	31.5	.75	2.75

[1]Total dose of FSH-P (porcine pituitary gonadotropin) divided into 4 or 6 equal doses and administered two or three times daily over two days starting 36 h after induced luteolysis ($PGF_{2\alpha}$, Lutalyse) on d 12 (5 PM).
*Difference between means for 5 AU and 7.5 AU doses of FSH-P, P < .05.

[1]Dwane R. Zimmerman is Professor of Animal Science and Laurie Grammer was a Research Technician in the Animal Science Department.

The Effects of Dietary Protein Concentration on Compensatory Growth in Barrows and Gilts

Phillip S. Miller
Darren J. Critser
Austin J. Lewis
Cynthia K. Wolverton[1]

Compensatory or "catch-up" growth is characterized by a period of accelerated growth after a period of feed restriction. Carcass composition, organ size, and metabolic activity are altered during feed restriction and refeeding. Therefore, examination of organ adaptations during periods of feed restriction in conjunction with the expression of accelerated growth rates during refeeding, support the use of compensatory growth as a model for the growing pig. In addition, the compensatory-growth model provides an effective research tool to examine different growth rates in pigs from the same genetic population without limiting feed intake or administering exogenous growth promotants.

The primary objective of this research was to determine the optimal dietary protein concentration required to maximize growth rate, feed efficiency, and carcass measurements in barrows and gilts exhibiting compensatory growth. The second objective was to determine the relationship between dietary protein concentration and organ weights in barrows and gilts exhibiting compensatory and normal growth.

Procedures

One hundred twenty crossbred pigs (60 barrows and 60 gilts) with an initial weight of approximately 92 lb were used. Thirty barrows and 30 gilts were offered a maintenance level of feed for 21 days. Feed allotments were adjusted weekly to minimize weight loss or gain. At the end of the 21-day restriction period, the restricted barrows and gilts weighed 87.5 lb. After the 21-day restriction period, barrows and gilts were allowed ad libitum access to one of five experimental diets until a weight of approximately 225 lb was achieved. In addition, 30 barrows and 30 gilts were allowed ad libitum access to one of the five experimental diets for the entire experimental period (92 to 225 lb). All pigs were individually penned in an environmentally controlled building.

Diets were corn-soybean meal based and formulated to contain one of five crude protein percentages (13.1, 14.4, 15.8, 17.1, and 18.4%; Table 1). All other nutrient concentrations were equal to, or in excess of, NRC requirements. The 17.1% crude protein diet was provided during the restriction period. Daily feed allotments during the restriction period were based on each pig's maintenance energy requirement. Because nutrient densities were not adjusted in the diet provided during the restriction period, the daily intake of all nutrients were below NRC requirements for growth.

Feed consumption (disappearance) and pig weights were recorded weekly. Carcass measurements and organ weights were collected and recorded at slaughter (225 lb). Carcass lean percentage was calculated using the National Pork Producer's Council equation (Procedures to Evaluate Market Hogs, Third Edition, 1991). Gastrointestinal contents were removed for the determination of empty-body weight (live weight minus gastrointestinal content weight).

Results

Restricted-refed (R) pigs took 12 days longer ($P < .05$) to reach 225 lb than pigs that were allowed ad libitum access (AL) to feed. Growth performance data are provided in Table 2. During the ad libitum feeding period, average daily feed intake (ADFI), average daily gain (ADG), and gain/feed were greater in R compared to AL pigs (ADFI, 6.42 vs 5.78 lb, $P < .0001$; ADG, 2.27 vs 1.96 lb, $P < .0001$; gain/feed, .36 vs .34, $P < .1$). For the entire experimental period, AL pigs consumed 15% more ($P < .001$) feed, gained weight 19% faster ($P < .0001$), and were more ($P < .05$) efficient than R pigs.

Barrows consumed more feed and had a greater rate of gain than gilts (ADFI, 6.37 vs 5.84 lb, $P < .0001$; ADG,

(Continued on next page)

Table 1. Composition of diets[a]

	Dietary crude protein percentage				
Ingredient, %	13.1	14.4	15.8	17.1	18.4
Ground corn	84.05	80.35	76.60	72.90	69.20
Soybean meal (44% CP)	13.45	17.20	21.00	24.75	28.55
Dicalcium phosphate	.95	.90	.80	.75	.65
Ground limestone	.45	.45	.50	.50	.50
Salt	.30	.30	.30	.30	.30
Vitamin premix	.70	.70	.70	.70	.70
Trace mineral premix	.10	.10	.10	.10	.10
Calculated analysis:					
Metabolizable energy, Mcal/lb	1.50	1.50	1.49	1.49	1.49
Chemical analysis, %:					
Crude protein	13.70	14.80	16.50	17.70	18.60
Lysine	.62	.70	.86	.95	1.04
Calcium	.60	.58	.59	.58	.61
Phosphorus	.47	.45	.46	.48	.47

[a]As-fed basis.

Table 2. The influence of feeding regimen and dietary crude protein concentration on the growth performance of barrows and gilts

		AL[a]					R[a]				
Item	CP,%	13.1	14.4	15.8	17.1	18.4	13.1	14.4	15.8	17.1	18.4
Number	B[b]	6	6	6	6	6	6	6	6	6	6
	G	6	6	6	6	6	6	6	6	6	5
Ad libitum feeding period											
Average daily feed intake, lb[c,d]	B	6.24	6.06	6.00	5.45	6.06	6.57	6.95	6.92	6.86	6.57
	G	6.04	5.34	5.47	5.76	5.47	6.33	5.64	5.91	6.59	5.82
Average daily gain, lb[c,d,e]	B	2.21	2.25	1.85	1.94	1.87	2.38	2.43	2.43	2.34	2.34
	G	1.85	1.87	1.90	1.92	1.98	2.01	1.98	2.27	2.18	2.25
Gain/feed[e]	B	.35	.37	.31	.36	.31	.36	.35	.35	.34	.36
	G	.31	.35	.35	.34	.36	.32	.36	.39	.34	.39
Entire Experimental Period											
Average daily feed intake, lb[c,d,e]	B	6.24	6.06	6.00	5.45	6.06	5.09	5.36	5.29	5.27	5.09
	G	6.04	5.36	5.47	5.76	5.36	5.09	4.61	4.67	5.25	4.65
Average daily gain, lb[c,d,e]	B	2.21	2.25	1.85	1.94	1.87	1.70	1.74	1.72	1.65	1.68
	G	1.85	1.87	1.90	1.92	1.98	1.50	1.50	1.65	1.61	1.65
Gain/feed[f]	B	.35	.37	.31	.36	.31	.34	.33	.33	.32	.33
	G	.31	.35	.35	.34	.36	.30	.33	.36	.31	.35

[a]AL = Ad libitum, R = Restricted. Ad libitum pigs had ad libitum access to feed for the entire experimental period (92 to 225 lb). Restricted pigs were fed to maintain weight for 21 days and subsequently allowed ad libitum access to feed until slaughter (225 lb).
[b]B = barrows, G = gilts.
[c]AL vs R, P < .0001.
[d]Sex effect, P < .005.
[e]Protein x sex interaction, P < .05.
[f]AL vs R, P < .05.

2.20 vs 2.02 lb, P < .0005) during the ad libitum feeding period. Similar response in ADFI and ADG were observed in barrows and gilts when data were pooled over the entire experimental period. No difference (P > .1) was observed for gain/feed between barrows and gilts for either the ad libitum feeding or entire experimental period. No effect (P > .1) of dietary crude protein concentration on performance criteria was detected. There was an interaction (P < .05) between dietary crude protein concentration and sex. Gilts consumed less feed, gained more weight, and were more efficient as dietary protein concentration increased.

Gilt carcasses had greater (P < .001) longissimus muscle area, less (P < .0001) fat at the tenth rib, and increased (P < .0001) calculated lean percentage compared to barrows (Table 3). There were no differences (P > .1) in carcass measurements due to feeding regimen or crude protein concentration.

Table 3. Carcass measurements and backfat thickness of barrows and gilts

Item	Barrows	Gilts	P[a] <
Number	60	59	
Hot carcass weight, lb	155.54	156.97	NS[b]
Longissimus muscle area, in^2	4.38	4.87	.001
Tenth-rib fat depth, in	1.07	.92	.0001
Lean tissue, %[c]	45.46	48.94	.0001

[a]Probability value.
[b]Nonsignificant, P > .1.
[c]Calculated using the National Pork Producer's Council equation (NPPC, 1991).

No differences (P > .1) in organ weights were observed between AL and R pigs. The empty-body weight of gilts was greater (P < .05) than that of barrows. This indicated that gastrointestinal fill was greater in barrows (Table 4). Heart and kidney weights were less (P < .05) in barrows compared to gilts. Liver weight was 5% greater (P < .05) in barrows than gilts. There was a linear increase (P < .05) in liver and kidney weights as dietary protein concentration increased.

Conclusions

Pigs fed to maintain body weight for 21 days and then allowed ad libitum access to feed had increased growth rates compared to pigs allowed ad libitum access to feed during the entire experimental period (92 to 225 lb). The difference in liver weight between barrows and gilts may be attributed to differences in feed intake. The linear increases in liver and kidney weights associated with increasing dietary crude pro-

Table 4. Final live, empty-body and organ weights of barrows and gilts

Item		Dietary Crude Protein Concentration, %				
		13.1	14.4	15.8	17.1	18.4
Number	B[b]	12	12	12	12	12
	G	12	12	12	12	11
Final live weight, lb	B	225.7	226.9	224.5	222.9	225.6
	G	226.0	227.3	227.7	227.4	226.2
EBW[a,c], lb	B	200.3	200.6	198.2	196.3	198.9
	G	203.2	200.4	201.9	200.2	199.5
Organ weight, lb						
Heart[c]	B	.73	.78	.68	.71	.72
	G	.80	.74	.80	.77	.80
Liver[c,d]	B	3.11	3.29	3.29	3.39	3.26
	G	2.90	3.12	3.07	3.21	3.22
Kidney[c,d]	B	.64	.67	.66	.72	.69
	G	.68	.69	.68	.75	.75
Small intestine	B	2.90	3.05	2.95	2.87	2.68
	G	2.75	2.76	2.76	2.73	2.85

[a]Empty-body weight. Empty-body weight was used as a covariate in the statistical analyses of organ weights.
[b]B = barrows, G = gilts.
[c]Sex effect, $P < .05$.
[d]Linear effect of dietary protein concentration, $P < .05$.

tein concentration may be related to the metabolism of excess nitrogen and excretion of urea.

Under the dietary conditions used in this study, these data do not support the hypothesis that pigs exhibiting compensatory growth require a different dietary crude protein concentration to maximize performance. However, the elevation in feed intake and the response of feed efficiency observed during refeeding do suggest that pigs require a greater quantity of dietary protein to exhibit compensatory growth.

Our future research in this area will focus on the metabolic adaptations that occur in the growing-finishing pig exhibiting compensatory growth. This information will help refine the definition of nutrients required to support growth processes in pigs with different genetic capacities to deposit lean tissue.

[1]Phillip S. Miller is an Assistant Professor, Darren J. Critser is a Graduate Student, Austin J. Lewis is a Professor, and Cynthia K. Wolverton is a Research Technologist, Department of Animal Science.

Evaluation of a Soybean Meal:Soy Lecithin:Soapstock Mixture for Nursery Pigs

Phillip S. Miller
Austin J. Lewis
Cynthia K. Wolverton[1]

Soybeans are processed and refined to produce many products that are used extensively for both edible and inedible purposes. Over 35 billion pounds of soybean oil and 36 to 40 million tons of soybean meal are produced annually. During the soybean oil extraction and refining process, several byproducts are produced. Two of the major byproducts are soy lecithin and soapstock (Figure 1).

Lecithin is a phospholipid that comprises approximately 2% of the extracted oil (700 million lb annually). The major use of soy lecithin is as an emulsifier in feeds and foods and inedible products. Soapstock is composed of sodium salts of fatty acids and is used mainly in rendered animal feeds. Unfortunately, the production of both soy lecithin and soapstock exceed current industry demands.

The main objective of this research was to evaluate the use of a soybean meal:soy lecithin:soapstock (SSS) mixture as a feed ingredient in comparison to conventual fat sources (tallow and choice white grease) on the growth performance of nursery pigs.

Procedures

Two experiments were conducted to evaluate a SSS mixture for nursery pigs. A total of 480 crossbred pigs were used (240 pigs/experiment). Both experiments were conducted in the same nursery facility (12 pens with 10 barrows and 10 gilts/pen; pen dimensions, 4 ft x 20 ft). Pigs used in Experiments 1 and 2 were weaned 28 ± 3 days postfarrowing. Nursery temperature was maintained at 77° F for the first two weeks and reduced to 72° F for the remainder of the experimental periods. In addition, heat lamps were placed in each pen for the duration of the experiments.

In Experiment 1, dietary treatments were started one week after weaning. Pigs were weaned and immediately started on respective treatments in Experiment 2. During both experiments, pigs had ad libitum access to feed and water. In both experiments, feed disappearance was calculated and pigs were weighed weekly.

Four dietary treatments were used in Experiment 1 (Table 1):

(Continued on next page)

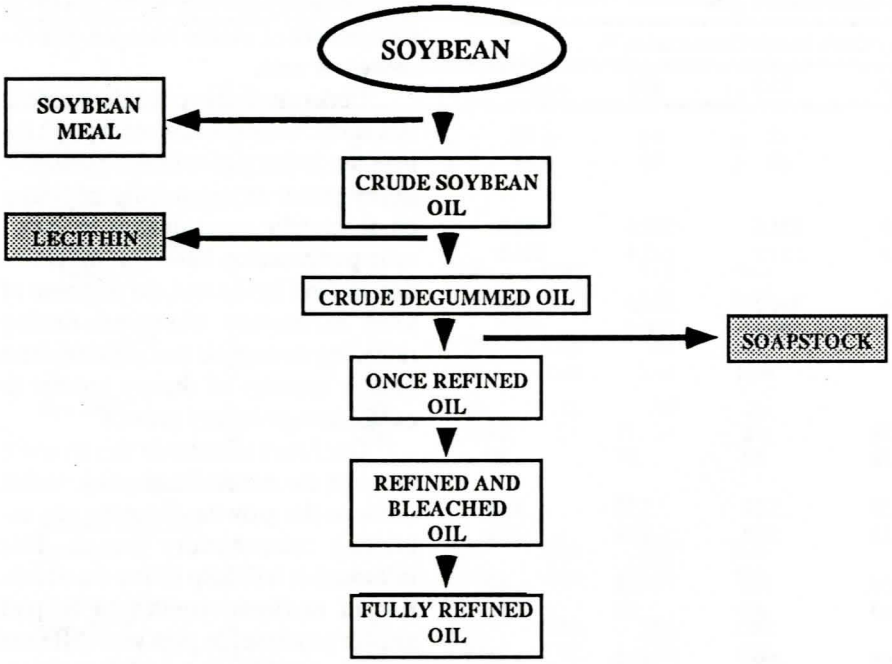


Figure 1. Products of soybean oil refining.

1. A control, corn-soybean meal diet formulated to contain 1.2% lysine.
2. A corn-soybean meal diet with 4% added tallow formulated to contain 1.2% lysine.
3. A corn-SSS diet formulated to contain 1.2% lysine.
4. A corn-soybean diet with both the SSS mixture and 4% tallow added formulated to contain 1.2% lysine.

In Experiment 2, a two-phase feeding system utilizing complex-nursery diets was used. Phase 1 diets were formulated to contain 1.3% lysine and were provided for the first two weeks post-weaning. Phase 2 diets were formulated to contain 1.25% lysine and were provided during the subsequent three-week period. Three dietary treatments were used in Experiment 2 (Table 2):

1. A control, corn-soybean meal-fishmeal-whey diet.
2. A corn-soybean meal-fishmeal-whey diet with 4% (Phase 1) or 3.6% (Phase 2) choice white grease added.
3. A corn-SSS mixture-fishmeal-whey diet.

The level of choice white grease was decreased in the Phase 2 diet (from 4 to 3.6%) because the lipid contribution from the soy lecithin and soapstock was reduced by lowering the percentage of soybean meal added. It was assumed that the combination of soy lecithin and soapstock contained 75% of the metabolizable energy of choice white grease.

Results

Experiment 1 (Table 3): Average daily gain was not affected (P>.1) by the addition of the SSS mixture or tallow to the diet. Feed intake tended to decrease (P < .1) when lipids were added to the diet. Pigs consumed 6% more (P < .05) of the SSS diet compared to the tallow diet. The addition of both SSS and tallow reduced feed intake (P < .01) compared to the single additions of either SSS or tallow. Feed efficiency (gain/feed) tended to improve (P < .1) when lipids were added to the diet. Gain/feed tended to improve further (P<.1) with the addition of both SSS and tallow

Experiment 2 (Table 4): Early performance (first two weeks) was poor. Average daily gain ranged from .36 to .40 lb. Gains improved during the last three weeks of the study. For the entire five-week period, pigs fed diets that contained choice white grease and SSS consumed more feed and gained faster than pigs fed the control diet, but the differences were not statistically significant. Overall, the increase in feed intake was relatively greater than the increase in gain for pigs consuming the SSS diet. Therefore, there was a trend for

Table 1.Composition and analysis of diets fed in Experiment 1[a]

	Treatments[b]			
Ingredient, %	CON	SSS	TAL	SSSTAL
Corn	61.10	53.80	56.40	49.80
Soybean meal (44% CP)	35.95	—	36.65	—
Soybean meal:soy lecithin:soapstock[c]	—	43.25	—	43.25
Tallow	—	—	4.00	4.00
Dicalcium phosphate	1.25	1.25	1.25	1.25
Limestone	.30	.30	.30	.30
Salt	.30	.30	.30	.30
Trace mineral premix	.10	.10	.10	.10
Vitamin premix	1.00	1.00	1.00	1.00
Analysis:				
Metabolizable energy, Mcal/lb (calculated)	1.47	1.52	1.56	1.61
Crude protein, %	20.8	20.9	21.0	21.2
Lysine, %	1.16	1.15	1.12	1.13
Calcium, %	.67	.67	.69	.70
Phosphorus, %	.58	.64	.56	.65

[a]As-fed basis.
[b]Abbreviations are: CON = control, SSS = soybean meal:soy lecithin:soapstock, TAL = tallow, and SSSTAL = soybean meal:soy lecithin:soapstock and tallow.
[c]Each pound of the soybean meal:soapstock:soy lecithin mixture contained .86 lb soybean meal, .046 lb soapstock, and .094 lb soy lecithin.

Table 2. Composition and analysis of diets fed in Experiment 2[a]

	Treatments[b]					
	Phase 1[c]			Phase 2		
Ingredient, %	CON	CWG	SSS	CON	CWG	SSS
Corn	52.70	48.70	47.40	53.95	49.55	48.20
Soybean meal (44% CP)	28.75	29.10	—	31.85	32.20	—
Soybean meal:soy lecithin: soapstock mixture[d]	—	—	34.00	—	—	37.50
Fishmeal	5.00	5.00	5.00	2.50	2.50	2.50
Whey	10.00	10.00	10.00	7.50	7.50	7.50
Choice white grease	—	3.60	—	—	4.00	—
Salt	.30	.30	.30	.30	.30	.30
Monosodium phosphate	.65	.70	.70	.95	1.00	1.05
Limestone	.45	.45	.45	.80	.80	.80
Trace mineral premix	.10	.10	.10	.10	.10	.10
Vitamin premix	1.00	1.00	1.00	1.00	1.00	1.00
Copper sulfate	.05	.05	.05	.05	.05	.05
Mecadox premix	1.00	1.00	1.00	1.00	1.00	1.00
Analysis:						
Metabolizable energy, Mcal/lb (Calculated)	1.47	1.54	1.51	1.46	1.54	1.50
Crude protein, %	21.8	21.4	21.4	20.3	19.7	19.9
Lysine, %	1.09	1.12	1.11	1.03	1.05	1.06
Calcium, %	.86	.89	.88	.77	.79	.83
Phosphorus, %	.72	.72	.77	.70	.70	.70

[a]As-fed basis.
[b]Abbreviations are: CON = control, CWG = choice white grease, and SSS = soybean meal: soy lecithin:soapstock.
[c]Phase 1 diets were provided for the first two weeks postweaning and Phase 2 diets were provided for the subsequent three-week period.
[d]Each pound of the soybean meal:soy lecithin:soapstock mixture contained .86 lb soybean meal, .046 lb soapstock, and .094 lb soy lecithin.

Table 3. Performance of pigs in Experiment 1

	Treatment[a]			
Item	CON	SSS	TAL	SSSTAL
Number	60	60	60	60
Weight, lb				
Initial[b]	19.01	18.60	19.14	18.95
Final	44.41	45.27	44.36	44.70
Average daily gain, lb	.91	.96	.90	.92
Average daily feed intake, lb[c,d,e]	1.71	1.73	1.63	1.59
Gain/feed[c,f]	.532	.550	.553	.579

[a]Abbreviations are: CON = control, SSS = soybean meal:soy lecithin:soapstock, TAL = tallow, and SSSTAL soybean meal:soy lecithin:soapstock and tallow.
[b]Treatment effect, P < .1. Initial weight was used as a covariate in the statistical analysis of treatment effects on average daily gain, average daily feed intake, and gain/feed.
[c]CON vs SSS + TAL + SSSTAL; P < .1.
[d]SSS vs TAL; P < .05.
[e]SSSTAL vs SSS + TAL; P < .01.
[f]SSSTAL vs SSS + TAL; P < .1.

gain/feed to be reduced (P < .1) in the SSS versus the choice white grease group. Analyzed lysine concentration in both Phase 1 and 2 diets was significantly lower than formulated values. The discrepancy between the analyzed and formulated lysine levels may partially explain the reduced performance during the Phase 1 period.

Conclusions

No detrimental effects were seen with addition of the SSS mixture to nursery diets. Results from Experiment 1 suggest that nursery pigs offered a corn-soybean meal based diet consumed more feed and were equally as efficient when soy lecithin and soapstock were added to soybean meal compared to tallow. Results from Experiment 2 which used a two-phase feeding system numerically supported the results of Experiment 1. Poor performance during the first phase warrants further investigation of these products in conjunction with nursery diets that include milk and animal/fish protein sources. In addition, future analyses should examine the economic comparison of soybean meal:soy lecithin:soapstock mixtures to traditional lipid sources such as tallow and vegetable oils. Direct application of soy lecithin and soapstock to soybean meal can provide soybean processors a method to efficiently transfer these byproducts into animal feeds. Also, this application can potentially alleviate the problem of over production of these byproducts.

Table 4. Performance of pigs in Experiment 2

	Treatment[a]		
Item	CON	CWG	SSS
Number	80	80	80
Weight, lb			
Initial	16.45	16.54	16.63
Week 2	21.52	22.03	22.23
Final	45.91	47.29	47.91
Average daily gain, lb			
Phase 1[b]	.36	.39	.40
Phase 2[b]	1.16	1.20	1.22
Total	.84	.88	.90
Average daily feed intake, lb			
Phase 1	.62	.62	.68
Phase 2	2.09	2.23	2.32
Total	1.52	1.58	1.66
Gain/feed			
Phase 1	.578	.628	.582
Phase 2	.548	.542	.531
Total[c]	.553	.555	.540

[a]Abbreviations are: CON = control, CWG = choice white grease, and SSS = soybean meal: soy lecithin:soapstock.
[b]Phase 1 refers to the first two-week period postweaning and Phase 2 refers to the subsequent three-week period.
[c]CWG vs SSS; P < .1.

[1]Phillip S. Miller is an Assistant Professor, Austin J. Lewis is a Professor, and Cynthia K. Wolverton is a Research Technologist, Department of Animal Science

Degrees and Diets for Weaned Pigs

Michael C. Brumm
David P. Shelton[1]

Previous research at the University of Nebraska's Northeast Research and Extension Center has shown that weaned pigs respond favorably to a pattern of reduced nocturnal temperatures. When the temperature in the pig zone was lowered up to 10 F° from 7 p.m. to 7 a.m. from a control temperature regimen (86° F first week post-weaning, then lowered 3.6 F° per week) beginning one week after weaning, weaned pigs responded with a 6.8% increase in overall nursery feed intake and a 5.3% increase in overall daily gain. In these previous trials, weaned pigs were fed a commercial nursery diet formulated to contain 1.15% lysine and 1515 Kcal metabolizable energy (ME)/lb.

It is possible that the weaned pig will respond favorably to longer periods of reduced nocturnal temperatures than those previously researched. In addition, if reduced nocturnal temperatures stimulate feed intake, a diet sequence lower in lysine content should result in equal pig performance at a potential feed cost savings.

To explore these possibilities, an experiment using 360 pigs weaned at three to four weeks of age with an average initial weight of 17 lb was conducted. Three winter trials were conducted during a two-year period.

The facility used was a two-room nursery at the Northeast Research and Extension Center at Concord. Each nursery room had comparable ventilation, heating, and manure handling systems. The two rooms were alternated between control and reduced temperature treatments from trial to trial. Within each room, pigs were housed six per pen in ten 4 ft x 4 ft pens with open mesh partitions, 100% woven wire flooring, a three-hole self feeder and one nipple drinker.

The furnace thermostat in the room with the control treatment was set to maintain a temperature of 86° F during the first week post-weaning. Room temperatures were then decreased 3.6 F° per week. In the room with reduced nocturnal temperatures (RNT16), during the first week post-weaning and during eight hours per day (8 a.m. to 4 p.m.) for the remainder of each trial, the temperature was maintained the same as the control room. Starting with the second week in each trial, for a 16 hour period (4 p.m. to 8 a.m.), thermostat settings were reduced approximately 10 F° from the daytime temperature. Dual thermostats, with sensing elements at pig height and controlled by a time clock, were used for furnace control. A minimum ventilation pit fan ran continuously in each room.

The composition of the experimental nursery diets is given in table 1. All pigs received the 1.2% lysine diet for the first week post-weaning. Beginning with the imposition of the experimental temperature treatments, one-half of the pigs (five pens) within each room were switched to the 1.1% lysine diet. On the week a pen of pigs averaged 23 lbs liveweight or greater, they were switched to the nursery diet that was 0.2% lower in lysine. Lysine content was varied by altering the ratio of corn and soybean meal.

After the five-week nursery period, pigs were sorted by size within diet and temperature treatment groups and grown to market weight in partially slatted confinement facilities to evaluate carry-over effects the nursery treatments might have had on growing- finishing performance. Pigs were housed ten per pen with one four-hole feeder and one nipple drinker. A corn-soy diet formulated to contain 0.8% lysine was fed for the duration of the growing-finishing period.

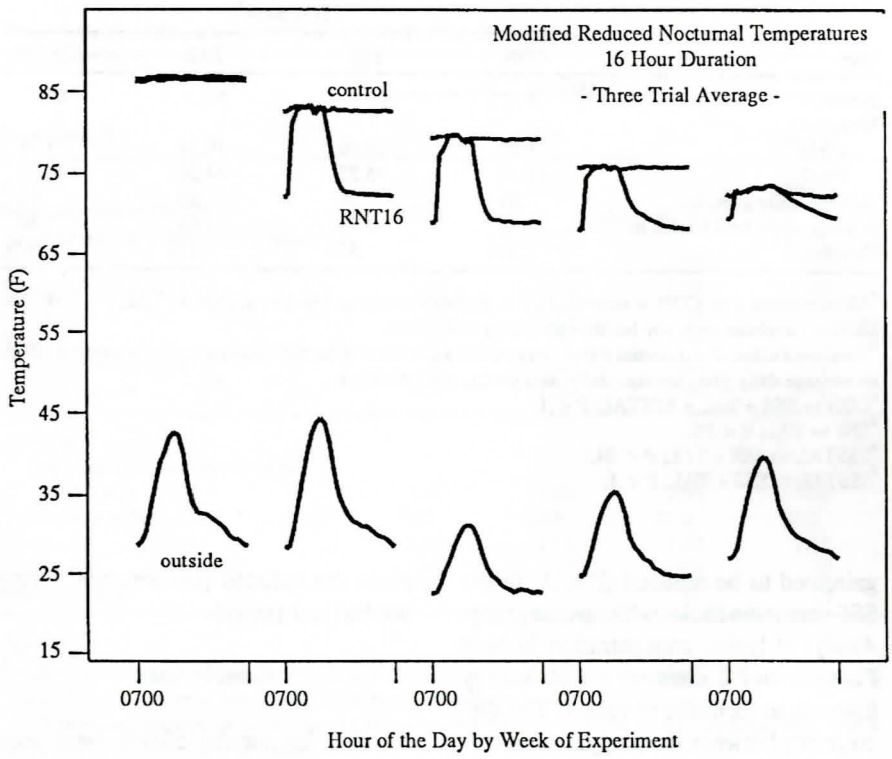


Figure 1. Temperatures in pig zone and outside the research facility.

Results

Figure 1 is a plot of the hourly temperature by week at pig height averaged across all trials. While a definite daily temperature fluctuation was achieved for the RNT16 treatment, the rate of cool down was dependent on outside air temperature, pig size and building mass. As the pigs grew, nighttime target temperatures were generally not reached until the early morning hours, if at all. Above normal outside temperatures in all three trials resulted in cool down rates and fuel savings that were reduced compared to expected average conditions. This was especially true in trial 2 (January 23 to February 27, 1992), as outside temperatures averaged almost 10 F° above normal. Averaged across the three trials, 14% fewer heating degree days were accumulated because of the warmer outside temperatures.

There was no interaction between nursery temperature regimen and diet sequence on any performance parameter measured. Table 2 presents the results for the main effects of nursery temperature treatment and diet sequence on nursery and subsequent grow-finish performance. Unlike the 12-hour RNT sequence evaluated in earlier studies, 16 hr of a reduced temperature regimen did not stimulate feed intake or result in improved gain compared to the control regimen. Because of the warm outside temperatures already noted for trial 2, overall utility savings averaged only $.35 per pig weaned. There was no difference in death loss due to nursery temperature treatment.

Because pigs on the RNT16 treatment did not eat more nursery feed, there was no interaction of diet and temperature. As a consequence, nursery pigs offered diets lower in lysine weighed less at the end of the 35-day nursery period and had a poorer feed conversion.

During the subsequent growing-finishing period, pigs on the RNT16 treatment ate more feed, but this increase in feed intake resulted in a nonsignificant increase of only 2.4% in daily gain and no difference in feed conversion. There was no effect of nursery diet on grower-finisher gain, feed intake, feed conversion efficiency or death loss.

Table 1. Experimental Diets

Item	Diet (% lysine) 1.2	1.1	1.0	0.9
Ingredient	----------	----------	%	----------
Corn	50.25	53.95	65.20	68.80
44 SBM	25.75	22.05	28.80	25.20
Fat	3.00	3.00	3.00	3.00
Edible whey	15.00	15.00		
Menhaden fish meal	4.00	4.00		
Limestone	.40	.40	.75	.75
Dical	1.00	1.00	1.65	1.65
Salt	.30	.30	.30	.30
Vit/TM premix	.25	.25	.25	.25
Copper sulfate	.05	.05	.05	.05
Calculated analysis				
Crude protein, %	20.0	18.7	18.2	16.9
Lysine, %	1.20	1.10	1.00	0.90
Threonine, %	.85	.80	.72	.68
Tryptophan, %	.26	.24	.24	.22
ME, Kcal/lb	1534	1538	1541	1544

Table 2. Summary of pig performance and utility use - three trials.

	Nursery temperature[a]		Nursery diet sequence[b]		
	Control	RNT16	1.2/1.0	1.2/1.1/0.9	SE
Nursery performance					
No. pens	30	30	30	30	
Weight, lb					
Initial	16.9	17.0	16.9	17.0	
Final[c]	43.3	44.1	44.8	42.7	.3
ADG, lb[c]	.75	.77	.79	.73	.01
ADF, lb	1.50	1.53	1.51	1.51	.02
F/G, lb/lb[c]	1.99	1.98	1.91	2.06	.02
Dead/Removed, %	1.1	1.1	1.1	1.1	
Utility cost[d]	$332.94	$269.54			
Grower-finisher performance					
No. pens	18	18	18	18	
Final wt., lb	235.3	236.2	235.7	235.8	.7
ADG, lb	1.66	1.70	1.67	1.69	.01
ADF, lb[e]	5.36	5.49	5.41	5.44	.05
F/G, lb	3.22	3.24	3.24	3.21	.03
Dead/removed, %	2.8	1.1	1.7	2.2	

[a]Control = 86°F during wk 1, reduced 3.6°F per week thereafter; RNT16 = same temperature as control during wk 1, thereafter thermostats maintained same as control from 8 a.m. to 4p.m., and lowered 10°F remainder of day.
[b]1.2/1.0 = 1.2% lysine in the diet until avg weight equaled 23 lbs, 1.0% lysine thereafter; 1.2/1.1/.9 = 1.2% lysine in the diet during wk 1, 1.1% until average weight equaled 23 lbs, and .9% thereafter.
[c]Diet effect (P < .0001).
[d]Propane = $.70/gal, Elec. = $.05/Kwh.
[e]Temperature effect (P < .075).

Lowering nighttime room air temperatures in pig nurseries continues to offer the potential of reduced utility expenses with no negative effects on pig performance. These results suggest that weaned pigs may require only a "block" of heat each day, with this "block" being as short as eight hours, instead of the previously recommended 24 hr period of constant air temperature.

Recommendations

Producers considering the use of reduced nighttime temperatures in nurseries are urged to observe the following cautions:

1) Good nursery facilities are required. The desired sleeping

(Continued on next page)

area should be draft free (air movement < 0.30 ft/min). Adequate ventilation for moisture control must be provided.

2) Do not reduce nighttime temperatures until the newly weaned pigs are eating aggressively. In most cases, wait one week postweaning before reducing ambient temperature.
3) Turn down the furnace thermostat no more than 10°F from the recommended daytime setting for a 12-16 hr period.
4) Do not lower nutrient density of nursery diets similar to those used in these trials with the expectation of an increase in feed intake (i.e. nutrients).

[1]Michael C. Brumm is a Professor of Animal Science and an Extension Swine Specialist and David P. Shelton is a Professor of Biological Systems Engineering and an Extension Ag Engineer at the Northeast Research and Extension Center, University of Nebraska-Lincoln, Concord, Nebraska.

Meal Patterns of Weanling Pigs Fed Diets Containing Either Spray-Dried Porcine Plasma or Dried Skim Milk

Paul M. Ermer
Phillip S. Miller
Austin J. Lewis[1]

In the 1992 Nebraska Swine Report, we described the preference of weanling pigs for diets containing spray-dried porcine plasma (SDPP) over those containing dried skim milk (DSM). Because preference for the SDPP diet increased throughout the 21-day postweaning period, we hypothesized that preference was due to increased palatability, and not novelty. If SDPP were novel to the weanling pig, preference for a SDPP diet should decrease with time. The present experiment was conducted to test the hypothesis that increased consumption of diets containing SDPP is due to increased palatability.

Materials and Methods

Sixteen crossbred weanling pigs that weighed 15.9 lb and were 26 days of age were individually allotted to receive either a diet containing SDPP or one containing DSM (Table 1). There were two trials of eight pigs each. Pigs were allotted according to litter with littermates in pens directly opposite each other (two rows of pens) and allotted to different diets. Pens were 3 ft x 7 ft with coated wire floors. Room temperature was maintained at 85° F for the first week and gradually reduced to 80° F by the third week of each trial. There was continuous fluorescent lighting. Diets were identical to those described in the 1992 Nebraska Swine Report. The SDPP diet contained 8.5% SDPP and 20% dried whey, and the DSM diet contained 20% each of dried skim milk and dried whey. Lactose was added to the SDPP diet to equal the amount of lactose contributed by the dried skim milk in the DSM diet. Pigs had ad libitum access to diets throughout the experiment and feed intake was recorded daily. Body weight was recorded weekly throughout the 21-day experiment.

On days 3, 7, and 14, feeding behavior was observed continuously by one person for 18 hours (0600 to 2400). The time spent consuming feed and the time between feedings were recorded. After 10 minutes of no feeding, feeders were weighed. Pigs were considered to be feeding when observed with their head in the feeder and chewing feed.

For each pig during each 18-hour period, periods of feeding were characterized into meals. Meals were considered to be periods of feeding separated by intervals of relatively short duration (usually 10 minutes or less). These brief, and frequent, intervals represented drinking or other activities associated with the meal. Longer (30 minutes to several hours), and less frequent, intervals represented sleeping or other activities. Previously developed statistical methods were used to establish whether an interval was categorized as occurring during the course of a meal or between meals. These methods rely primarily on the frequency of occurrence to determine the probability of an interval belonging in either category.

Feed consumption rate was calculated by dividing intake during the 18-hour observation period by the duration of time spent consuming feed. Similarly, the percentage of time spent consuming feed was obtained by dividing

Table 1. Diet composition (%)[a]

Ingredient	SDPP	DSM
Corn	38.32	38.55
Soybean meal (44% CP)	16.90	16.40
Spray-dried porcine plasma[b]	8.50	—
Dried skim milk	—	20.00
Dried whey	20.00	20.00
Lactose	10.00	—
Soybean oil	3.00	3.00
Dicalcium phosphate	1.60	.50
Vitamin mix	1.00	1.00
Salt	.25	.25
DL-methionine	.13	—
Trace mineral mix	.10	.10
Copper sulfate	.10	.10
Aureomycin 50	.10	.10
Nutrient	**Analyzed composition**	
ME, kcal/lb[c]	1,592	1,660
Crude protein, %	19.24	19.38
Lysine, %	1.28	1.30
Methionine, %	.33	.33
Calcium, %	.76	.76
Phosphorus, %	.64	.61
Sodium, %[c]	.79	.48

[a]SDPP = spray-dried porcine plasma, DSM = dried skim milk.
[b]Spray-dried porcine plasma (AP620) donated by American Protein Corporation, Ames, IA.
[c]Calculated.

the duration of time spent consuming feed by the total length of the observation period (18 hours).

Results

Daily feed intake of pigs receiving either a diet containing SDPP or DSM is depicted in Figure 1. Although the difference was not significant (P = .38), pigs fed the SDPP diet consumed 27 and 6% more feed than those fed DSM during the first 7 days and during the entire 21-day period, respectively. This confirms research at both Iowa and Kansas State Universities which indicates that weanling pigs will consume more of a diet containing SDPP for approximately the first two weeks postweaning, after which consumption of a SDPP and a DSM diet are approximately equal.

A total of 724 meals were consumed during the three 18-hour observation periods. However, because feeder weights could not be obtained to coincide exactly with all meals, 606 meals, accounting for 89% of feed intake, were used in the analysis of meal size.

Increased consumption of the SDPP diet was reflected by an increased (P < .05) rate of feed consumption on days 3 and 7 during the intensive measurements (Table 2). There was no overall effect of diet (P > .10) on the number of meals, the size of meals, or the percentage of time spent consuming feed. However, pigs fed the SDPP diet consumed larger meals than pigs fed the DSM diet on days 3 and 7, whereas pigs fed the DSM diet consumed larger meals than pigs fed the SDPP diet on day 14 (time x diet interaction, P = .05).

There was no difference (P > .10) between treatments in ADG throughout the experiment (Table 3). However, there was a tendency toward lower feed:gain for pigs fed the DSM diet (P < .10).

Discussion

These results support the hypothesis that diets containing SDPP may be more palatable than those containing DSM. The short-term (approximately 1 week) increase in feed intake observed in pigs that consumed the SDPP diet was a result of increased rate of feed consumption and meal size. By day 14, increased consumption of the DSM diet was associated with increased meal size. This may have been an attempt to compensate for lower intake during the first week.

Research at Iowa State University has shown that increased consumption of a SDPP diet was accompanied by reduced feed efficiency. Australian researchers have found that, at similar feed intakes, increasing meal size and reducing the number of meals consumed resulted in reduced feed efficiency when diets contain a large proportion of crystalline amino acids. Our results are consistent with the majority of research that indicates that meal patterns have no effect on feed efficiency.

Both meal size and rate of feed consumption increased throughout the first two weeks postweaning. Increases in rate of consumption may be partly attributable to increased size of the oral cavity as the pig matures.

Caution should be used when extrapolating results of preference tests to situations where only one diet is

(Continued on next page)

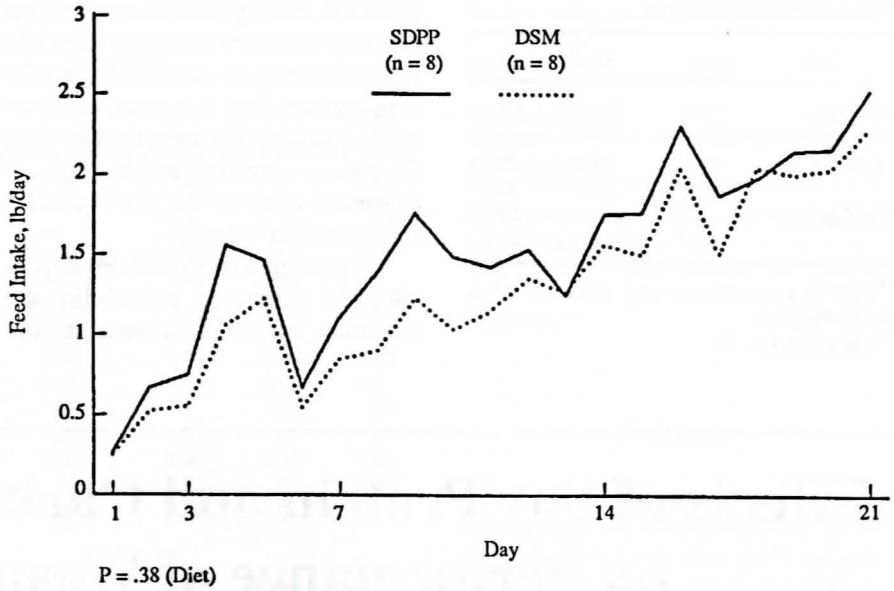


Figure 1. Consumption of diets containing either spray-dried porcine plasma (SDPP) or dried skim milk (DSM) throughout 21 days postweaning.

Table 2. Meal patterns of weanling pigs fed diets containing either SDPP or DSM[a]

		Day[b]		
Criteria	Diet	3	7	14
Number of meals	SDPP	16.24	17.00	16.63
	DSM	15.36	14.00	16.00
Size of meals, oz[cd]	SDPP	1.24	1.27	1.44
	DSM	.83	1.05	1.62
Rate of consumption, oz/minute[ce]	SDPP	.016	.018	.020
	DSM	.011	.012	.020
Percentage of time consuming feed, %	SDPP	14.90	11.17	10.52
	DSM	12.24	8.86	12.80

[a]SDPP is spray-dried porcine plasma; DSM is dried skim milk.
[b]Values are for 18 h period (0600 to 2400) on the day indicated.
[c]Day effect, P < .05.
[d]Diet x day interaction, P = .05.
[e]SDPP vs DSM, P < .05.

Table 3. Performance data

Criteria	Day	Diet[a] SDPP	DSM
ADG, lb	1-7	.044	.027
	1-21	.182	.182
Feed:gain	1-7	2.63	2.86
	1-21[b]	1.64	1.52

[a]SDPP is spray-dried porcine plasma; DSM is dried skim milk
[b]Diet effect, P = .06.

provided. In our previous research, pigs preferred the SDPP diet to the DSM diet and preference increased throughout 21 days postweaning. However, when not offered a choice between the two diets (as in the present experiment), pigs only consumed more of the SDPP diet for approximately 7 days.

The compound(s) in SDPP responsible for increased palatability are unknown. The reason for the decrease in the feed intake response to SDPP after one to two weeks postweaning is also unknown. Nevertheless, depending on costs of ingredients, SDPP may be cost effective for pigs weighing less than 15 lb.

[1]Paul M. Ermer is a graduate student, Phillip S. Miller is an Assistant Professor, and Austin J. Lewis is a Professor, Department of Animal Science.

Effects of Soy Protein and Carbohydrate Source on Performance of Weanling Pigs

E. A. Newton
C. K. Wolverton
A. J. Lewis
P. S. Miller[1]

Pigs weaned at three weeks of age or less benefit from the addition of a highly digestible source of carbohydrate to the diet. This is not surprising given the fact that the secretion of digestive enzymes, particularly those that digest starch do not reach mature levels until the pig is four to five weeks of age. Addition of milk products such as dried whey or dried skim milk to the diet of young pigs generally improves digestion and feed utilization. Dried whey is most commonly used because of its low cost relative to other milk products such as dried whey. Historically, most of the benefit of dried whey was thought to be due to its protein component (lactalbumin). However, recent studies have shown that although both the protein and carbohydrate (lactose) fractions of dried whey are well utilized by young pigs, lactose may be of greater importance than milk protein.

Another ingredient commonly included in pig diets is soybean meal, a source of highly digestible protein when properly processed to denature harmful substances such as trypsin inhibitors. Even when the inhibitor content is low, performance of early weaned pigs fed diets containing soybean meal is lower than that of pigs fed products high in milk proteins. Recently, researchers have suggested that the presence of antigenic compounds, such as glycinin and β-conglycinin, are responsible for this reduction in performance. To overcome these detrimental effects, replacement of soybean meal with soy products that have undergone further processing and have low levels of antigenic compounds should result in enhanced growth performance during the early postweaning period.

The objective of our research was to evaluate the performance of early weaned pigs fed a practical diet formulated with either soybean meal or soy protein concentrate as the primary source of dietary protein, and with the addition of either dried whey, cornstarch, or lactose as the carbohydrate source.

Methods

One hundred eighty crossbred barrows and gilts with an initial weight of 14.1 ± 1.3 lb were used. Pigs were blocked by initial weight and sex (five pigs per pen) and assigned to one of six dietary treatments which they received for 21 days. Pens were equipped with one four-hole feeder and one nipple-waterer.

Compositions and analyses of the six diets are listed in Tables 1 and 2. Two protein (soybean meal and soy protein concentrate) and three carbohydrate (cornstarch, dried whey, and lactose) sources were used. Diets were formulated to contain 1.3% lysine, .90% calcium, and .80% phosphorus. Dried whey was added at 20% of the diet (14.4% lactose equivalent), whereas cornstarch and lactose were included at 14.4%. Pigs were allowed ad libitum access to feed and water throughout the entire experiment.

Pigs were weighed and feed intakes were determined weekly. Average daily feed intake, average daily gain, and gain/feed were determined. The pen of pigs was considered the experimental unit. Data were analyzed using appropriate statistical procedures that included initial weight as a covariate.

Results

There were no interactions between protein and carbohydrate sources. Therefore, main effects are listed in Table 3.

Pigs that consumed the soy protein concentrate diets had greater growth rates at two weeks postweaning than pigs fed the soybean meal diets (P<.10). However, feed intakes and gain/feed were not affected by protein source. For the entire three-week study, weight gain, feed intake, and gain/feed were numerically (but not statistically) greater for pigs fed soy protein concentrate than soybean meal.

Table 1. Composition and chemical analysis of experimental diets

	Treatment[a]					
	SBM			SPC		
Ingredient, %	DW	CS	LAC	DW	CS	LAC
Corn	37.80	42.40	42.40	49.20	53.90	53.90
Soybean meal (44% CP)	35.10	35.10	35.10	—	—	—
Soy protein concentrate	—	—	—	23.50	23.50	23.50
Dried whey	20.00	—	—	20.00	—	—
Cornstarch	—	14.40	—	—	14.40	—
Lactose	—	—	14.40	—	—	14.40
L-lysine. HCl	—	.18	.18	—	.18	.18
Corn oil	3.00	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.70	2.45	2.45	1.91	2.5	2.5
Calcium carbonate	.01	.03	.03	—	.02	.02
Salt	.30	.30	.30	.30	.30	.30
Vitamin mix	1.00	1.00	1.00	1.00	1.00	1.00
Trace mineral mix	.10	.10	.10	.10	.10	.10
Antibiotic	1.00	1.00	1.00	1.00	1.00	1.00
Chemical analysis, %						
Crude protein	21.00	20.10	19.90	21.40	20.20	20.30
Lysine	1.12	1.19	1.17	1.15	1.17	1.17
Threonine	.85	.76	.74	.89	.76	.76
Methionine	.32	.30	.31	.31	.32	.30
Cystine	.43	.39	.40	.40	.40	.40
Phenylalanine	.95	.94	.92	1.00	.94	.94
Tyrosine	.60	.59	.57	.62	.59	.60
Histidine	.51	.51	.50	.53	.52	.51
Leucine	1.69	1.61	1.57	1.81	1.65	1.65
Isoleucine	.82	.77	.74	.87	.76	.76
Valine	.91	.85	.82	.97	.85	.85
Calcium	.85	.83	.78	.83	.88	.89
Phosphorus	.77	.77	.69	.79	.80	.80
ME, Mcal/lb (calculated)	1.51	1.53	1.53	1.47	1.50	1.50

[a]Abbreviations are SBM = soybean meal, SPC = soy protein concentrate, DW = dried whey, CS = cornstarch, LAC = lactose.

Table 2. Analysis of soy protein sources[a]

Analysis	SBM	SPC
Trypsin inhibitor[b]	< 3	< 3
Glycinin[c]	> 12	< 1
β-conglycinin[c]	7	< 1

[a]Abbreviations are: SBM = soybean meal, SPC = soy protein concentrate.
[b]Milligrams of trypsin inhibited per gram of sample.
[c]Titers ($\log_2$).

Summary

Performance was enhanced in early weaned pigs fed diets containing highly digestible protein and carbohydrate sources. Soy protein concentrate, a highly digestible protein source containing low concentrations of growth inhibitors and antigenic compounds, improved gain and feed intake during the first two weeks postweaning. Dried whey and lactose improved gain and tended to increase feed intake and efficiency during the first two weeks postweaning compared to cornstarch. Dried whey was more effective than lactose in improving efficiency during the first two weeks postweaning.

Pigs that consumed diets containing either dried whey or lactose had greater weight gains during the first two weeks postweaning than pigs fed diets with cornstarch (P<.05). Feed intake and gain/feed tended to be greater during the first two weeks postweaning when diets contained either dried whey or lactose rather than cornstarch.

No differences were detected between pigs fed lactose or dried whey for weight gain or feed intake at two weeks postweaning, or at the end of the trial. However, at two weeks postweaning, pigs fed dried whey were more efficient in converting feed to gain than were pigs fed lactose. Dried whey and lactose improved feed intake compared to diets containing cornstarch for the entire three-week study.

Table 3. Effects of protein and carbohydrate source on performance of weaned pigs[a]

	Treatment				
	Protein		Carbohydrate		
	SBM	SPC	DW	CS	LAC
Number	90	90	60	60	60
Initial wt, lb	14.09	14.09	14.07	14.13	14.09
Final wt, lb¶	24.12	24.86	24.55	24.08	24.82
Average daily gain, lb					
d 0-7	.216	.237	.246	.192	.240
d 0-14¶*	.367	.416	.416	.352	.406
d 0-21	.477	.506	.489	.475	.511
Average daily feed intake, lb					
d 0-7	.399	.397	.387	.380	.427
d 0-14	.578	.619	.589	.561	.645
d 0-21*	.795	.837	.814	.769	.866
Gain/feed					
d 0-7	.474	.502	.532	.458	.745
d 0-14§	.641	.671	.700	.636	.632
d 0-21	.605	.611	.612	.620	.593

[a]Abbreviations are: SBM = soybean meal, SPC = soy protein concentrate, DW = dried whey, CS = cornstarch, LAC = lactose.
¶Soybean meal vs soy protein concentrate (P < .10).
*Cornstarch vs dried whey and lactose (P < .05).
§Dried whey vs lactose (P < .05).

Conclusion

Including a further processed soy protein that has reduced concentrations of factors that may be antigenic to pigs results in improved growth performance during the early postweaning period. After the first two weeks postweaning, there was no additional benefit to feeding soy protein concentrate. Early weaned pigs benefit from lactose inclusion in the diet, either as lactose alone or from dried whey.

Providing diets containing a protein source low in inhibitors such as soy protein concentrate and a high quality carbohydrate source such as dried whey to early weaned pigs is beneficial. When weanling pigs reach approximately 20 lb body weight, they should be switched to a less complex, corn-soybean meal-based diet

[1]E. A. Newton was a Postdoctoral Associate, C. K. Wolverton is a Research Technologist, A. J. Lewis is a Professor, and P. S. Miller is an Assistant Professor, Department of Animal Science.

Nutrient Recommendations for Pigs In Denmark

Duane E. Reese[1]

Denmark exports about 80% of the pork it produces and the Danes' customers have long sought pork with a low fat content. Therefore, by combining skills in genetic selection, nutrition, disease control, marketing and business management, many Danish pig producers sell pigs that weigh 225 lb and average 59% lean. In addition, sows produce on the average 20.6 feeder pigs per year. Because of the increasing emphasis on value-based marketing and sow productivity in the US, it is relevant to examine pig nutrient recommendations from Denmark.

A committee of pig researchers from the National Institute of Animal Science and the Federation of Slaughterhouses and local extension advisors from the Farmer's Unions reviews data from Denmark and several international sources. The committee's final feeding recommendations include safety margins; however, the recommendations are considered minimal standards necessary for optimum production in Denmark. All pigs except gestating sows, breeding boars, replacement gilts and finishing pigs (restricted at 90 to 95% of ad libitum) are assumed to have ad libitum access to feed.

Since 1976, Denmark has used an energy evaluation system based on net energy to ensure more accuracy in diet formulation, hence greater control over composition of growth. Danish pig producers use feedstuffs that vary widely in fiber content, thus it is important to consider the actual productive power (or net energy) of each feedstuff when formulating diets. In Denmark, dietary amino acid, vitamin and mineral recommendations are expressed in amounts per unit of dietary net energy.

In the US, dietary energy concentration is usually described as metabolizable energy (ME). Amino acid, vitamin and mineral recommendations are commonly given to producers as percent of the diet or amounts per ton of complete feed.

For convenience, the Danish nutrient recommendations were converted to a US standard. First, the dietary ME levels in Table 1 were used. The ME values were calculated using standard values for individual ingredients and diets based on corn-soybean meal or milo-soybean meal. The Starter A and Lactation diets contain 3% added fat.

In Denmark, amino acid recommendations are expressed in terms of digestible amino acids rather than total amino acids to ensure more accuracy in diet formulation. Pig producers in the US commonly see amino acid requirements expressed as total levels which are adequate for corn-soybean or milo-soybean based diets. Thus, digestible amino acid levels were converted to a total basis using fecal digestibility coefficients calculated for each amino acid. The amino acid values in this paper are *total levels* and refer to corn-soybean meal or milo-soybean meal diets containing the ME levels shown in Table 1.

Recommendations

Nutrient recommendations for pigs in Denmark are shown in Tables 2, 3 and 4. The amino acid, vitamin and mineral recommendations for 13 to 220 lb pigs apply to growing gilts and barrows. Feeding barrows and gilts different diets is not encouraged in Denmark because feed intake differences are diminished due to restricted feeding. Replacement gilts should be fed the same level of nutrients as gilts and barrows for slaughter until they weigh 130 lb. Beginning at 130 lb until breeding, replacement gilts should receive the same nutrient standards as shown for lactating sows.

Recent Danish research indicates that the amino acid recommendations are also sufficient for growing boars that are fed ad libitum, suggesting that the levels are too high for barrows given ad libitum access to feed. In addition, Danish research suggests that the amino acid recommendations for gilts during the late finishing stage, which are allowed ad libitum access to feed, are slightly

Table 1. Dietary Metabolizable Energy (ME) Level (as-fed basis)

Type of diet Body wt, lb	Starter A 13-20	Starter B 20-55	Grower 55-110	Finisher 110-220	Gestation	Lactation
ME, Mcal/lb	1.50	1.45	1.46	1.47	1.44	1.52

Table 2. Danish amino acid recommendations (as-fed basis)[a,b]

	Total Level, %					
Type of diet	Starter A	Starter B	Grower	Finisher	Gestation	Lactation
Body wt, lb	13-20	20-55	55-110	110-220		
Feed intake, lb/d			3.5	5.5	4.6	12
Lysine	1.40	1.27	1.02	0.93	0.46	0.80
Tryptophan	0.25	0.20	0.20	0.18	0.13	0.17
Threonine	0.83	0.74	0.68	0.63	0.43	0.60

[a]For corn-soybean meal or milo-soybean meal based diets.
[b]Adapted from Normer for Naeringsstoffer, Landsudvalget For Svin.

Table 3. Danish vitamin recommendations (as-fed basis)[a]

	Additions/ton			
Type of diet	Starter A	Starter B	Grower-Finisher	Breeding Herd[b]
Body wt, lb	13-20	20-55	55-220	
Vitamin A, million IU	8	5	4	8
Vitamin D_3, thousand IU	820	490	395	775
Vitamin E, thousand IU	40	40	40	40
Vitamin K, g[c]	2	2	2	2
Riboflavin, g	4	4	2	5
Niacin, g	20	20	20	20
Pantothenic acid, g	10	10	10	15
Biotin, mg	200	200	50	200
Vitamin B_{12}, mg	20	20	20	20
Folic acid, g	0	0	0	1.5
Thiamin, g	2	2	2	2
Pyridoxine, g	3	3	3	3

[a]Adapted from Normer for Naeringsstoffer, Landsudvalget For Svin.
[b]Based on a feeding level of 4.6 lb/d for gestating sows and gilts.
[c]Menadione activity.

Table 4. Danish mineral recommendations (as-fed basis)[a]

	Total Level					
Type of diet	Starter A	Starter B	Grower	Finisher	Gestation	Lactation
Body wt, lb	13-20	20-55	55-110	110-220		
Feed intake, lb/d			3.5	5.5	4.6	12
Calcium, %	0.73	0.92	0.87	0.66	0.85	0.90
Phosphorus, %[b]	0.68	0.80	0.70	0.55	0.70	0.75
Salt, %	0.3	0.3	0.3	0.3	0.3	0.3
Copper, g/ton	6	6	6	6	6	6
Iodine, g/ton	0.2	0.2	0.2	0.2	0.2	0.2
Iron, g/ton	155	145	80	80	80	80
Manganese, g/ton	40	40	40	40	40	40
Selenium, g/ton	0.36	0.34	0.2	0.2	0.2	0.2
Zinc, g/ton	100	100	100	100	100	100

[a]Adapted from Normer for Naeringsstoffer, Landsudvalget For Svin.
[b]For wheat-soybean meal or barley-soybean meal based diets.

overestimated.

Breeding boars should be fed a diet containing the amino acid levels described for lactation, according to the Danish recommendations. Recent University of Nebraska research supports this recommendation.

The vitamin recommendations in Table 3 are *additions per ton* of feed. Because of concerns about the stability and the relatively low cost of most vitamins, the Danes ignore the natural levels of vitamins in feedstuffs and simply add quantities to the feed sufficient to meet animal requirements. Many nutritionists in the US do the same.

The Danish committee suggests that vitamin E additions should be adjusted if certain conditions apply. When additions of a highly polyunsaturated fat (for example, soybean oil) exceed 4% of the diet, the vitamin E addition should be increased to about 60,000 IU per ton of feed. Furthermore, for stress-susceptible or Halothane-positive pigs, the suggestion is to increase addition of vitamin E to approximately 120,000 IU per ton of feed. The leading vitamin nutritionist in Denmark emphasizes that the basic level of vitamin E shown in Table 3 is quite adequate under most farm conditions and producers should not add greater amounts than are needed.

In contrast to many recommendations in the USA, choline is not added to breeding herd diets. The committee feels that sufficient choline is provided by natural sources and dietary methionine levels are high enough to act as an important methyl donor-one role choline plays in the diet. Also, in contrast to most US recommendations, biotin is included in growing pig diets. This is done because the bioavailability of biotin in small grains such as wheat and barley is less than that in corn and a deficiency is believed to increase the proportion of unsaturated fat in the carcass, causing meat quality problems. Thiamin and pyridoxine are added, although there are no data to support this practice.

The mineral recommendations in Table 4 are *total levels* in the feed. According to Danish law, total levels of selenium in feed can not exceed 0.45 g/ton (0.5 ppm); therefore, depending on diet composition, selenium additions may vary between 0.18 and 0.32 g/ton (0.2 and 0.35 ppm, respectively). Government restrictions also apply to levels of zinc, iron and copper in pig feed.

The Danish committee indicates that if the phosphorus requirement is met the ratio of calcium to phosphorus in feed can vary between 1:1 and 2:1. Also, no correlation between leg weakness and the calcium and phosphorus content of the diet has been found.

The phosphorus recommendations may seem low compared to some US standards for high-lean pigs. However, in Denmark barley and wheat, which contain more available phosphorus than corn and milo, is widely used in pig feed and there are public concerns about

(Continued on next page)

environmental pollution from excess phosphorus feeding.

Summary

This paper presents current Danish pig nutrient recommendations on a basis more familiar to US producers and nutritionists. For years Denmark has had a value-based marketing system based on carcass weight and percent lean. Consequently, certain genetic selection and nutritional programs, including restricted feeding were adopted. The Danish pig feeding recommendations can guide producers and nutritionists in the US who are feeding pigs intended for a value-based marketing system and who have sows capable of high productivity.

---

[1]Duane E. Reese is an Extension Swine Specialist in the Animal Science Department. He recently returned from a faculty study leave in Denmark and Sweden.

Selection for Size of Testes Increased Growth Rate But Did Not Affect Ovulation Rate and Puberty of Daughters

Rodger Johnson
Tom Rathje
Denise Drudik[1]

The reproductive rate of the sow herd is an important variable in the economic efficiency of producing lean pork. It can be improved by genetic selection as shown in research at Nebraska in which selection for increased litter size and decreased age at puberty were successful.

However, the rate of change from selection for these traits is usually less than for growth rate or backfat thickness. In selection for litter size, young boars and gilts can be selected only on records of female relatives. Gilts can be selected based on their own age at puberty, although measuring age at puberty on large numbers is costly, but as for litter size, boars can be selected only on records of relatives. For these reasons, accuracy and intensity of selection for reproductive traits are lower than for growth traits.

Because larger selection differentials are possible in males, selection response could be enhanced by including a male indicator trait along with direct measures of fertility in females. The trait should be easily measured, highly heritable, and highly correlated with the important female reproductive traits.

Work done in the 1970s with sheep and mice indicated testes size might be such a trait in pigs. Ovulation rate is an important component of litter size, and males in breeds of sheep with high ovulation rate had larger testes than males of other breeds. Females in lines of mice selected for increased size of testes had higher ovulation rate than control females. Furthermore, the physiological mechanisms of growth of testes are similar to those that lead to expression of puberty and ovulation in the female and selection for size of testes might decrease age at puberty in gilts.

To determine if female reproductive traits can be improved, selection for increased size of testes at 150 days of age was initiated in 1981. Select and control lines derived from the same base stock were maintained. Ten generations of selection have been completed. The objectives of this article are to report the direct response in testes size and correlated responses in age at puberty and ovulation rate in gilts. Because growth rate and backfat also are important, correlated responses in these traits in both boars and gilts are also reported.

Procedures

Population. Boars and sows of the Large White and Landrace breeds were crossed in 1979 to form a composite population. Three generations of random mating were practiced in this population. Pigs were then randomly assigned within litter to select and control lines and selection was initiated. Size of each line has been 40 to 45 litters each generation.

Selection criteria. Selection was for predicted weight of testes at 150 days of age. Width and length of paired testes were measured with calipers at approximately 140 and 160 days of age and used to predict weight of testes.

During the two generations of random mating before selection began, width and length of testes of boars were measured, boars were then castrated and the testes were weighed. From these data, an equation to predict weight of testes was developed. The equation for predicted weight of testes (PWT, ozs) was: PWT = [1.12 x W140] + [1.79 x L140] + [1.43 x W160] + [2.87 x L160] - 17.9, where W and L are width and length measurements (in) and 140 and 160 are days of age when boars' testes were measured.

Except in generations 7 and 8, all boars in the select line were measured and the 15 with the greatest PWT values were selected as breeders. In generations 7 and 8, one-half of the boars in each litter were randomly selected at weaning for another experiment. The number of boars measured was 78 in generation 7, 84 in generation 8, and between 136 and 187 in all other generations. In the control line, two boars were selected randomly at weaning from each half-sib family (a total of 30 boars) and one of them was randomly selected as a breeder. The number of boars measured each generation ranged from 29 to 33 in the control line. In both lines, 50 to 55 gilts were selected randomly with at least one gilt selected from each litter.

Management. Litters were weaned at 28 days of age and placed in nursery

pens. At approximately 56 days of age, pigs were moved to modified-open-front finishing buildings. There were 10 pigs per pen and pigs of only one sex in each building.

Boars were weighed when their testes were measured and their backfat was measured with a Renco Lean-Meter when 160-d measurements were made. Backfat was measured approximately 2 in off the midline at the locations of the fourth rib, last rib, and last lumbar vertebra. The three backfat measurements were averaged and adjusted to 188 lbs, the overall average weight of the boars.

All gilts in each pen were weighed when the oldest gilt was 130 to 135 days of age. Beginning at this age, they were taken daily to an adjacent building where they were allowed physical contact with a boar for 15 min and observed for signs of estrus. Age when a gilt first stood immobile for the boar and exhibited the typical symptoms of estrus was recorded as age at puberty. Gilts were weighed again and backfat was measured at approximately 180 days of age. Average backfat of gilts was adjusted to 202 lbs, the overall average weight of gilts.

During generations 5 and 10, a larger sample of gilts was retained so ovulation rate could be determined. In generation 5, 32 gilts per line were slaughtered 10 to 15 days after their second estrous period and their reproductive tracts were collected. Ovulation rate was measured by dissecting the ovaries and counting the corpora lutea. In generation 10, laparotomy was done 10 to 15 days after the second estrous period on 42 select and 40 control line gilts and corpora lutea on the ovaries were counted.

Analyses. To measure selection applied, selection differentials for testis size were calculated for each boar as the difference between his PWT value and the line-generation average PWT value. Cumulative selection differentials, which sum the total selection applied in the pedigree of each animal back to the base generation, were calculated for boars by averaging the cumulative selection differential of the boar's parents and adding the boar's own selection differential to this average. Cumulative selection differentials for gilts were calculated by averaging the cumulative selection differential of the gilt's parents.

Response to selection applied was estimated by regressing progeny performance for each trait on the average cumulative selection differential of the parents. Response per generation was estimated by deviating the record for each trait of animals in the select line from the control line mean and regressing these deviations on generation number.

Results

Means by generation and line for traits measured on boars are in Table 1 and means for traits of gilts are in Table 2. Estimates of genetic change in each

Table 1. Mean predicted weight of testes (PWT), cumulative selection differentials (CSD) for PWT, body weight at 140 (BW 140) and 160 days (BW 160), and backfat thickness (BF) at 188 lbs for boars of the select (S) and control (C) lines of each generation

	PWT, ozs		CSD, ozs		BW 140, lbs		BW 160, lbs		BF, in	
Generation	S	C	S	C	S	C	S	C	S	C
0	14.6	14.5			167.4	167.8	191.2	192.1	.74	.71
1	14.6	12.9	2.2	-.1	132.7	137.6	166.0	173.3	.86	.85
2	17.0	14.1	4.4	.7	158.1	155.7	194.7	192.5	.72	.68
3	15.8	12.3	6.6	.6	155.5	146.9	183.2	175.5	.76	.69
4	16.6	13.1	9.5	.5	151.7	143.1	183.7	175.3	.90	.83
5	15.7	11.6	12.4	.1	157.2	146.6	192.3	179.5	.76	.72
6	16.1	11.2	14.0	.4	164.3	154.6	199.1	187.4	.77	.81
7	19.5	14.5	16.1	.3	158.1	149.7	192.7	183.9	.81	.73
8	18.2	11.0	18.4	.3	176.8	151.0	210.1	184.1	.80	.84
9	16.5	10.6	20.3	.2	166.0	149.3	196.9	178.2	.91	.84
10	19.6	11.9	22.1	.4	158.5	142.9	194.0	175.7	.81	.74

Table 2. Mean weight at 130 (BW 130) and 180 days (BW 180), backfat at 202 lbs (BF), age at puberty (AP) and ovulation rate (OR) for gilts of the select (S) and control (C) lines

	BW 130, lbs		BW 180, lbs		BF, in		AP, d		OR	
Generation	S	C	S	C	S	C	S	C	S	C
0	138.9	139.8	201.5	199.3	.81	.78	176.2	182.3		
1	116.9	112.2	193.6	185.2	.91	.88	180.5	193.7		
2	138.9	144.2	205.1	208.4	.78	.72	171.8	185.1		
3	133.2	127.7	210.4	197.8	.80	.71	175.8	191.0		
4	133.2	127.7	206.8	197.6	.92	.85	169.5	185.7		
5	135.6	128.1	211.5	197.3	.82	.76	179.0	181.1	13.2	12.8
6	144.9	129.7	226.7	203.7	.87	.75	173.6	176.8		
7	140.0	123.3	211.7	198.0	.82	.72	169.3	171.0		
8	138.3	125.9	221.8	208.6	.89	.80	169.4	176.1		
9	141.3	129.4	215.6	203.3	.94	.82	174.7	180.2		
10	139.8	127.4	218.1	200.9	.86	.78	175.0	181.7	12.8	12.1

trait per unit of selection applied for PWT (regression on cumulative selection differential) and per generation (regression on generation), and heritabilities of the traits and genetic correlations of traits with PWT are in Table 3.

The select and control lines diverged consistently for PWT from generations 0 to 10. After 10 generations, a total of 22.1 ozs of selection had been applied and the lines diverged by 7.7 ozs (Table 1). The average change per generation was .65 ozs (P < .01) and the realized heritability of PWT was .35 (Table 3).

The lines also diverged for body weight of both boars (Table 1) and gilts (Table 2). At generation 10, boars of the select line weighed 15.6 lbs more at 140 days and 18.3 lbs more at 160 days than boars of the control line. Gilts of the select line were 12.4 lbs heavier at 130 days and 17.2 lbs heavier at 180 days than gilts of the control line. With the exception of the regression on generation for body weight of gilts at 180 days, estimates of change in body weight per unit of selection for PWT and per generation were significant (Table 3). Heritabilities of body weight ranged from .32 to .44 and all estimates of correlations of body weight with PWT were between .25 and .28.

Although the lines diverged for backfat thickness of both boars and gilts (Tables 1 and 2), estimates of change in backfat per unit of selection applied and per generation were not significant (Table 3). At generation 10, backfat thickness of select boars was .06 in greater than for control boars (Table 1), and gilts of the two lines differed by .08 in (Table 2). The heritability estimate of backfat was .34 and its correlation with PWT was found to be .17 in boars and .28 in gilts.

The response in age at puberty over generations was variable (Table 2). From generation 0 to 4, gilts of the select line consistently were younger at puberty and the difference between the lines was increasing. However, from generations 5 to 7 age at puberty was similar for the two lines and then there was again some divergence to generation 10.

Because age at puberty for the control line increased during the early generations of the experiment and then decreased at a rate faster than for the select line, the regression of line differences on generation number was positive (Table 3). This is interpreted to mean gilts of the select line were increasing in age at puberty relative to gilts of the control line over generations. However, when response was measured per unit of selection for PWT the estimated response in the select line was negative, but not significant. Most of this variation probably was due to random genetic change and environmental variation over generations. Even though age at puberty was highly heritable (estimated heritability of .55), its genetic correlation with PWT was estimated to be only -.08.

The difference between lines in ovulation rate was .4 eggs (P > .2) in generation 5, and .76 eggs (P < .10) in generation 10. Although not directly estimated from the data of this experiment, these differences in ovulation rate correspond to a genetic correlation of approximately .10 with PWT.

Table 3. Estimates of response per generation, per unit of cumulative selection differential (CSD) for predicted weight (PWT) of testes, heritabilities and genetic correlations of traits with PWT

	Regression on			
Trait[a]	Generation	CSD	Heritability	Genetic correlation with PWT
		Boars		
PWT, ozs	.65**	.35**	.35	
BW 140, lbs	2.09*	.81*	.32	.28
BW 160, lbs	2.49**	.94*	.34	.28
BF, in	.003	.003	.34	.17
		Gilts		
BW 130, lbs	1.55*	.62*	.31	.25
BW 180, lbs	1.41	.88*	.44	.25
BF, in	.006	.006*	.34	.28
AP, d	.80	-.37	.55	-.08

[a] PWT = predicted weight of testes at 150 days of age, BW = body weight at each age, BF = average probed backfat thickness, and AP = age at puberty.
* P < .05.
** P < .01.

Summary and Conclusions

Testes size will respond to selection. Variability among boars is high so large selection differentials can be realized. The realized heritability in this experiment was .35 and the response per generation was approximately 5.5% of the base generation mean. Correlated responses in body weight of boars and gilts between 130 and 180 days of age ranged from .7 to 1.6% per generation, and backfat increased at the rate of .4% in boars and .8% in gilts. Therefore, we conclude that selection for predicted weight of testes will change size of testes and cause correlated increases in rate of growth, and perhaps some increase in backfat thickness.

The experiment was done to determine whether selection for testes size could be done by producers to increase ovulation rate and decrease age at puberty of daughters. Responses in these traits were small and not significant. Estimates of the genetic correlations between predicted weight of testes and these reproductive traits of daughters were very low. Therefore selection for testes size to improve reproductive traits of daughters is not recommended.

[1]Rodger Johnson is a Professor, Tom Rathje is Research Technician and Denise Drudik was a student employee on the project in the Department of Animal Science at the University of Nebraska-Lincoln.

Selection for Size of Testes Decreased Age at Puberty of Boars

Rodger Johnson
Rusty Harder[1]

Improvements in reproductive traits of boars such as decreased age at puberty, increased rates of sperm production, and increased ease of mating would improve efficiency of pork production. These traits are difficult to measure and are expressed after selection decisions for growth, fat, and female reproductive traits are made. Therefore, effective selection for male reproductive traits is not possible within current industry selection practices.

Effective selection could be practiced by selecting for an indicator trait in young boars. The trait must be at least moderately heritable and genetically correlated with the traits of economic importance. Weight of testes predicted from measurements of width and length of paired testes might be such a trait. In the preceding report, we report results of ten generations of selection for increased predicted weight of testes at 150 days of age. The realized heritability was .35 and the response per generation was 5.5% of the base generation mean.

The objectives of this study are to characterize the morphology of the testes of boars of the select and the control lines from 70 to 450 days of age and to determine whether this selection decreased age at puberty of boars. Age at puberty was measured by rate of seminiferous tubule development and the age of boars when spermatids were first present in these tubules.

Methods

Population. Ten generations of selection for increased predicted weight of paired testes at 150 days of age or random selection were practiced. Weight of testes was predicted from width and length of paired testes at 140 and 160 days of age. The previous report contains the details of the selection experiment.

Procedure. A random sample of 75 boars of both the select and control lines from generation 8 was used. There were 15 half-sib families per line, and while in the nursery, five boars from each family were randomly selected and assigned to be castrated at either 70, 100, 130, 160, or 450 days of age.

At 56 days of age, boars were placed in a modified open-front building with 9 to 10 pigs per pen. They ate, ad libitum, a diet of corn, soybean meal, and premix calculated to contain 16% protein until the average weight of boars in a pen was approximately 130 lbs, and thereafter, a diet with 14% protein. Each boar was removed from its pen when it reached the treatment age to which it had been assigned. Boars in the 450-d treatment were moved to outside dirt lots at approximately 7 mo of age where they remained until they were castrated. During this time they were fed approximately 5 lbs per day of the 14% protein diet.

Each boar was weighed before it was castrated and was castrated while anesthetized. The left testis and epididymis were carefully separated, trimmed of connective tissue, and weighed. The right testis was immediately perfused via the testicular artery with a fixative and prepared for histological examination. Once prepared, slices of tissue from three sections (proximal, medial and distal regions) of each testis were mounted on slides for histological evaluations.

Testicular tissue is comprised largely of seminiferous tubules, the site of spermatogenesis and formation of spermatids, and Leydig cells, which produce the hormone testosterone, and vascularity. As the boar matures, the tubules increase in size and the center opens to form a lumen. During spermatogenesis, spermatids move from the cells within the tubules to the lumen through which they continue to move to the epididymis where they are stored until ejaculation.

Therefore size of seminiferous tubules, proportion of tubules with a lumen, and the presence of spermatids in the lumen of the tubules are measures of sexual development of the boar. Specific measurements made from microscopic examination of the testis tissue were the percentage of the testis occupied by seminiferous tubules, the percentage occupied by tubules with lumens, the percentage of tubules with lumens and with spermatids present, the percentage of testis occupied by Leydig cells, and the percentage of the testis occupied by vascularity.

Analyses were done to determine the pattern (linear or curvilinear) of the response in these variables as the boars increased in age, and to determine whether the pattern was different for the select and control lines.

Results

Boars of the select line were heavier at each age than control boars (Figure 1). Differences ranged from 2% at 70 days to 5% at 160 days. Lines differed ($P < .05$) and growth was curvilinear (significant cubic response), but the line by age interaction was not significant.

Differences between lines in testes weight and epididymides weight were larger than differences in body weight (Figure 2). There was a significant line by age interaction for both traits. Weight of testes of select line boars increased more rapidly between 70 and 160 days of age than testes of control boars. The difference was 37% at 70 days, 120% at 100 days, 92% at 130 days, 40% at 160 days, and 25% at 450 days.

(Continued on next page)

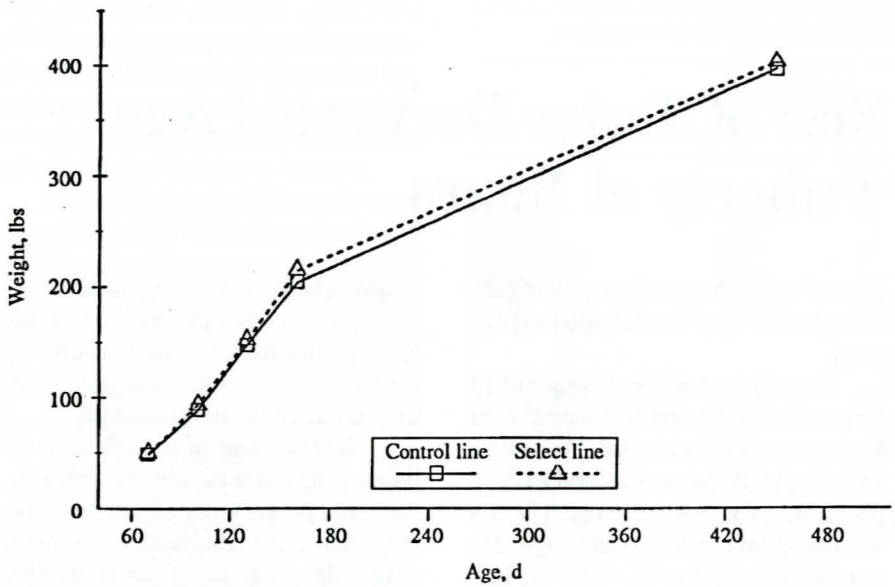


Figure 1. Body weight for select and control boars at 70,100, 130, 160, and 450 d of age

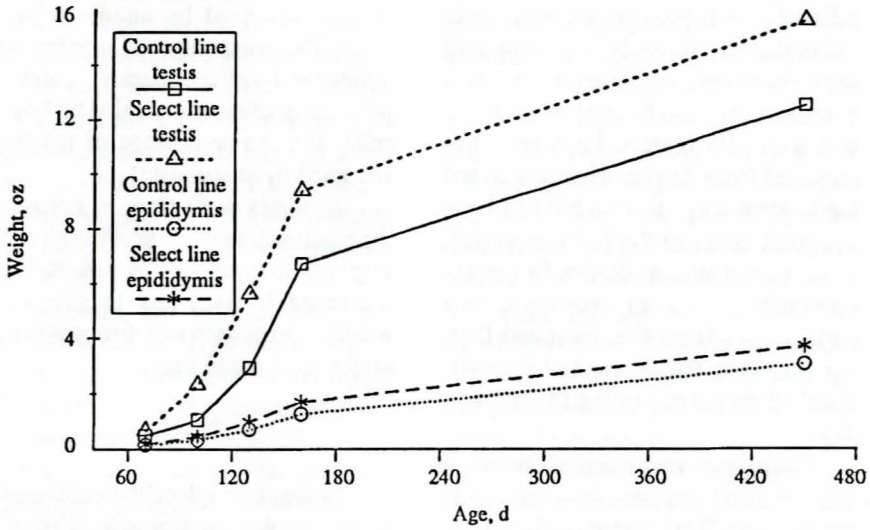


Figure 2. Weight of testes and epididymides for select and control boars at 70, 100, 130, 160 and 450 d of age.

The effects of age and line on weight of epididymides were similar to effects on weight of testes (Figure 2). The interaction of line and quadratic effect of age was significant. Differences between lines were 17% at 70 days, approximately 37% from 100 to 160 days, and 21% at 450 days.

There was a rapid increase in the percentage of the testis occupied by seminiferous tubules with lumens and a corresponding decrease in the percentage occupied by tubules without lumens between 70 and 160 days of age, but the changes occurred earlier in select line boars (Figure 3). Significant differences between lines for the percentage with lumens existed at 100 days (26%) and at 130 days (11%), but lines did not differ at 160 or 450 days.

Total volume of the testis composed of seminiferous tubules is shown in Figure 4. Lines differed, and the effect of age was cubic (both $P < .01$), but the line by age interaction was not significant. The difference between lines was 23% at 70 days, 26% at 100 days, 14% at 140 days, and 4% at 160 days.

Spermatids were not found in the lumens of tubules of any boar at 70 days of age (Figure 4). However, at all other ages, the mean percentage of tubules with lumens that contained spermatids was higher ($P < .10$) for the select line than the control line. The effect of age was quadratic, but the line by age interaction was not significant.

There was a decrease in the percentage of tubules with spermatids at 160 days, compared to 130 days, in both lines. This decrease likely reflects the rapid increase in tubules with lumens that occurred at earlier ages, and some of these tubules could have been in the early stage of development in which spermatogenesis had not been completed. The decrease probably does not reflect an actual decrease in sperm production.

Lines differed significantly in the percentage of the testis occupied by Leydig cells (Figure 5). The effect of age was cubic ($P < .01$), but the line by age interaction was not significant. Means were lower for the select line between 100 and 160 days of age, but line means were equal at 70 and 450 days of age. Lower values for the select line boars are not because there were fewer Leydig cells in their testes. Total mass of Leydig cells in the testes of select boars was greater at each age, but rate of seminiferous tubule development was greater during this period in select boars. The large differences between lines in weight of testes was mostly due to maturation of the seminiferous tubules and proliferation of Sertoli cells (cells of the tubules associated with spermatogenesis). Therefore the percentage of the testes occupied by Leydig cells was lower for select boars.

A significant line x age interaction existed for percentage of the testis composed of vascularity (Figure 5). The increase in the select line, and decrease in the control, from 70 to 130 days was probably due to different testis growth rates during this period. Rate of growth was very rapid in the select line, and if development of vessels did not keep

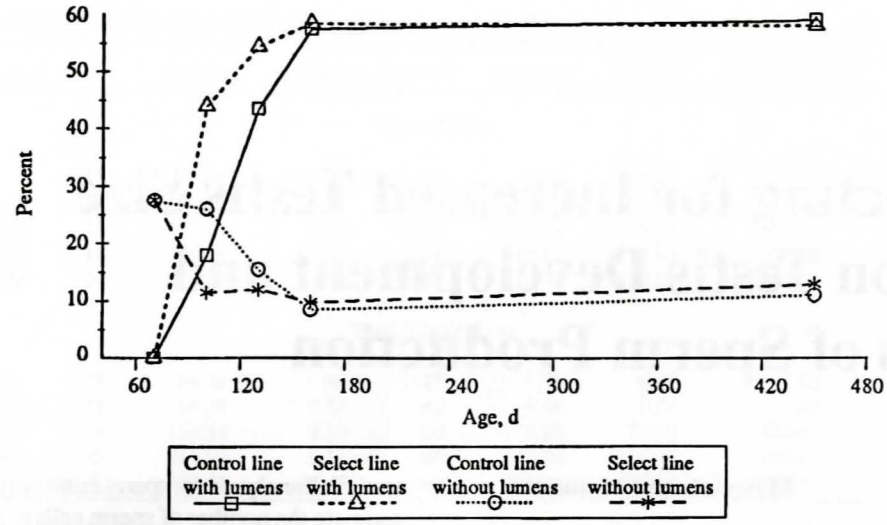


Figure 3. Percentage of testis composed of seminiferous tubules with and without lumens for select and control boars from 70 to 450 d of age.

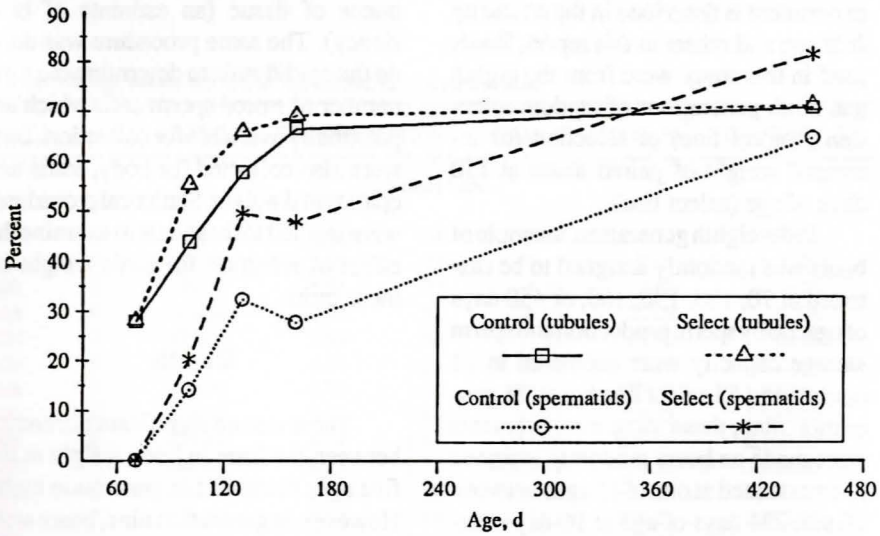


Figure 4. Testis (%) composed of seminiferous tubules (%) with spermatids for select and control boars from 70 to 450 d.

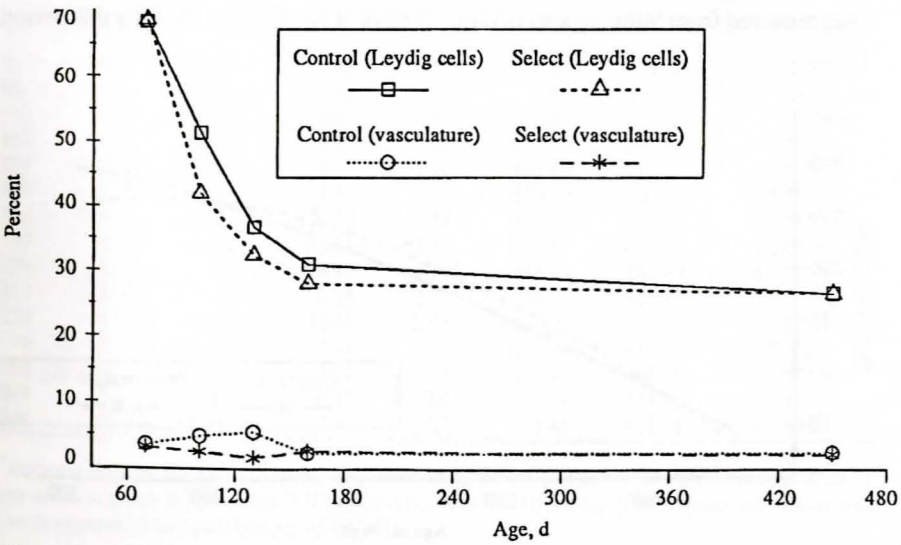


Figure 5. Percentage of the testis composed of Leydig cells and vasculature for select and control boars at 70, 100, 130, 160, and 450 d.

pace with proliferation of sertoli cells, the observed result would occur. The control line had a lower rate of testis growth, and the increase in growth rate occurred later than in the select line. Therefore, development of vascularity could have more closely paralleled testis growth until the period of rapid growth between 130 and 160 days.

Summary and Conclusions

Testes of boars developed rapidly between 70 and 160 days of age. Volume percentage of seminiferous tubules increased and volume percentage of Leydig cells decreased sharply during this period. In addition to increasing the size of testes at ages between 70 and 450 d, selection for weight of testes at 150 days caused earlier development of the testes in the select line.

The effect of selection was to initiate at a younger age the events that lead to puberty in the boar. These events lead to maturation of spermatozoa and release of spermatids into the lumens of seminiferous tubules. No spermatids were found in lumens of boars of either line at 70 days of age, but at all other ages a higher percentage of the lumens of boars of the select line contained spermatids. Also the increase in means with age was more rapid in the select line. Although the exact age at puberty could not be determined for each boar, we conclude that selection significantly reduced age at puberty.

Further, we conclude that body weight is not a primary factor controlling growth of testes. Select boars were heavier than control boars after 70 days of age, but unlike testis weight there was no age by line interaction. Furthermore, percentage differences between lines were much higher for weight of testes (25% to 120%) than for body weight (2% to 5%). Therefore, the lines had very different patterns of testis growth and rates of development of the testes, but similar patterns of body growth.

---

[1]Rodger Johnson is a Professor and Rusty Harder was a graduate student in Animal Science Department, University of Nebraska-Lincoln.

Effect of Selecting for Increased Testis Size in Boars on Testis Development and Rates of Sperm Production

Tom A. Rathje
Rodger K. Johnson[1]

Improving the reproductive ability of pigs has been traditionally accomplished through selection for female reproductive traits such as number born alive and decreased age at which first estrus occurs. Traits measured in boars which may affect reproductive capacity have not been as thoroughly studied as female traits. A genetically superior boar, in essence, produces sperm cells which are small packages of superior genes. An increase in production of sperm cells in a genetically superior male would allow more efficient distribution of his genetics. This idea is particularly applicable to the growing use of artificial insemination in the swine industry. In boars with greater ability to produce sperm cells, more doses of semen could be obtained from each ejaculate. One way in which sperm output may be increased is by selecting boars with larger testis size. Past studies have shown a positive correlation between testis size and the number of sperm cells within the testis.

The objectives of this study were: 1) To estimate daily sperm production and sperm production per ounce of testis tissue between 70 and 450 days of age in a line of pigs selected for increased size of testis for nine generations and a control line in which pigs were selected at random for nine generations; and 2) To estimate the number of mature sperm cells stored within the epididymis of boars in these same lines at these same ages.

Materials and Methods

Selection for increased weight of testes was begun in 1981. The selection experiment is described in the article by Johnson and others in this report. Boars used in this study were from the eighth and ninth generations of random selection (control line) or selection for increased weight of paired testes at 150 days of age (select line).

In the eighth generation, a sample of boars was randomly assigned to be castrated at 70, 100, 130, 160, or 450 days of age. Daily sperm production and sperm storage capacity were estimated in 71 control and 53 select line boars. In generation nine, these same measurements were made on boars randomly assigned to be castrated at one of 15 ages between 70 and 294 days of age at 16-day intervals. Testicular traits were measured on 74 control boars and 75 select line boars.

Following castration, tissue samples were removed from three regions of one testis and analyzed for sperm numbers to estimate the number of sperm cells produced per day by the testis and the number of sperm cells produced per ounce of tissue (an estimate of efficiency). The same procedure was done on the epididymis to determine the total number of stored sperm cells which are potentially available for collection. Data were also collected for body, testis and epididymal weight. Statistical procedures were applied to these data to examine the effect of selection for testis weight on these traits.

Results

There was no significant difference between the lines in body weight at the five ages measured in generation eight. However, in generation nine, boars were weighed at more frequent intervals and select line boars were found to be significantly heavier between 118 and 182 days of age (Figure 1). After this period,

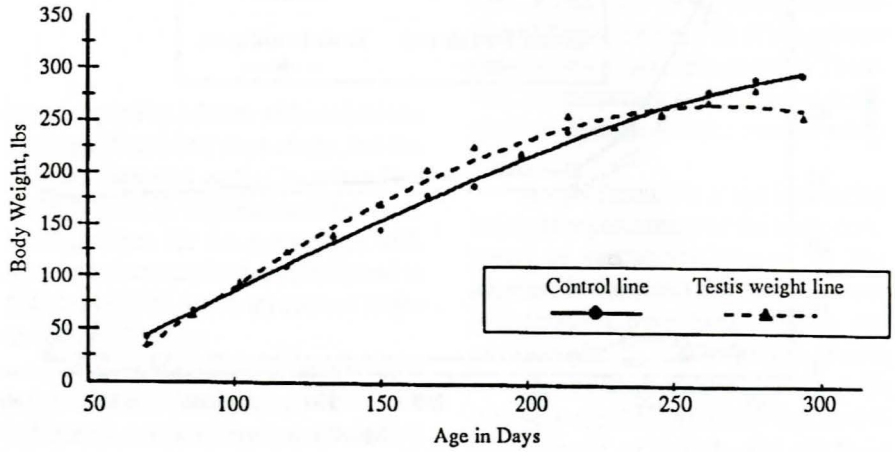


Figure 1. Body weight of boars in generation nine

Table 1. Mean values for traits[a] measured in generation eight

Age, d	n	BDWT	TRIMWT	EPIDWT	SPOZ, 10^7	DSP, 10^7	CAUDASP, 10^7
				Control Line			
70	15	48.84	.49	.15	2.61	0.23	0.80
100	15	92.40	1.27	.35	1.02	0.26	1.33
130	15	149.16	3.06	.74	19.83	15.73	95.83
160	12	203.06	6.82	1.24	91.62	120.91	1,040.50
450	14	401.94	12.92	3.11	173.32	430.39	4,829.46
				Testis Weight Line			
70	13	50.16	.66	.17	.71	0.09	1.23
100	13	94.38	2.35	.45	5.56	3.51	1.00
130	13	153.34	5.60	.99	57.80	73.00	294.63
160	9	216.04	9.21	1.60	118.04	213.15	1,904.17
450	5	407.44	15.47	3.84	190.74	552.94	4,852.50

[a]Body weight in lbs. (BDWT), testis and epididymis weight in oz. (TRIMWT, EPIDWT), sperm cell counts per ounce of parenchymal tissue (SPOZ), sperm cells produced per day (DSP), sperm cell counts in the cauda segment of the epididymis (CAUDASP).

Table 2. Mean values for traits[a] measured in generation nine

Age, d	n	BDWT	TRIMWT	EPIDWT	SPOZ, 10^7	DSP, 10^7	CAUDASP, 10^7
				Control Line			
70	5	42.90	.41	.14	1.50	0.14	0
86	5	67.32	.66	.25	0	0	0.06
102	5	89.98	1.58	.35	1.39	0.68	0.03
118	5	109.56	2.50	.53	26.73	20.08	12.05
134	5	139.04	3.99	.80	57.63	49.55	88.53
150	5	145.00	4.80	1.05	66.91	71.27	231.65
166	5	179.96	6.76	1.38	169.17	247.14	532.50
182	5	188.76	7.27	1.60	143.21	218.33	1,920.00
198	5	216.48	8.27	1.87	144.26	247.45	2,160.00
214	5	242.66	9.53	2.27	205.55	414.56	3,907.50
230	5	246.62	8.64	2.26	196.02	367.19	2,970.00
246	5	258.72	8.82	2.19	168.41	305.24	2,887.50
262	5	282.48	8.59	2.31	147.38	257.76	3,352.50
278	4	293.26	9.86	2.85	131.94	269.77	3,178.13
294	5	297.88	7.84	2.33	142.50	251.49	3,022.50
				Testis Weight Line			
70	5	34.14	.41	.12	4.34	0.33	0.51
86	5	65.52	1.41	.28	1.84	0.81	0
102	5	94.25	2.00	.51	2.47	1.09	0.12
118	5	122.23	4.85	.92	189.38	200.95	303.66
134	5	140.01	6.22	1.20	161.48	213.70	991.29
150	5	171.69	8.39	1.51	176.32	300.06	1,554.15
166	5	205.22	9.57	1.77	439.27	854.73	2,610.00
182	5	226.86	10.88	2.36	216.67	488.58	6,285.00
198	5	221.10	9.85	2.69	213.64	462.69	4,237.50
214	5	258.98	9.26	2.33	166.36	326.43	3,727.50
230	5	246.14	10.03	2.55	170.76	361.21	2,730.00
246	5	257.97	10.44	2.87	202.34	443.12	4,057.50
262	5	271.22	10.69	2.67	210.94	466.57	3,757.50
278	5	281.60	9.32	1.08	120.99	243.18	4,680.00
294	5	257.93	11.92	2.81	188.41	465.61	4,380.00

[a]Body weight in lbs. (BDWT), testis and epididymis weight in oz. (TRIMWT, EPIDWT), sperm cell counts per ounce of parenchymal tissue (SPOZ), sperm cells produced per day (DSP), sperm cell counts in the cauda segment of the epididymis (CAUDASP).

the growth of boars in the select line slowed and body weight plateaued at a value which was similar to that of control boars. In this experiment, boars from the select line had higher growth rates before and around the age of puberty, but did not differ from control boars in weight at later ages. Therefore, selection for testis weight may be a way to alter the growth curve in pigs.

Results for testis weight and epididymis weight were similar for generations eight and nine (Tables 1 and 2). Boars of the select line had testes and epididymides which increased in weight at a faster rate and weight of these organs plateaued at a higher value than for control boars. The differences between the lines in testes weight and epididymides were established during puberty and remained until 450 days of age. Select line boars were younger at puberty (see previous article by Johnson and Harder). The growth pattern for testes of select line boars was similar to control boars, but was shifted to younger ages.

Boars of both lines began producing sperm cells at similar ages (Tables 1 and 2); however, sperm produced per ounce of tissue and daily sperm production increased at a faster rate in select than control boars. In generation eight, differences between the lines in sperm production per ounce and daily sperm production established during puberty were maintained at 450 days of age (Table 1). In generation nine, sperm production per ounce of tissue in select line boars decreased to values similar to those for control boars after 200 days of age (Figure 2, panel a); however, differences between lines in daily sperm production established during puberty were maintained at 294 days of age (Figure 2, panel b). Therefore, in generation eight, select line boars had greater daily sperm production due to larger testis size and greater efficiency of sperm production, whereas in generation nine, the advantage of select line boars at older ages for daily sperm production was mostly due to larger testis weight.

No differences between the lines for number of sperm cells stored in the cauda epididymis were found in generation eight (Table 1). In generation nine,

(Continued on next page)

select line boars had the capacity to store larger numbers of sperm cells at younger ages than control boars, and their storage capacity increased faster and plateaued at a higher value (Table 2, Figure 2, panel c). Although semen collections were not made, males from the select line in generation nine should have had larger numbers of spermatozoa available for collection than control boars; however, differences between the lines in cauda sperm numbers were not found in generation eight. Perhaps this difference in response between generations occurred because boars were measured at several ages between puberty and maturity in generation nine, which permitted more accurate evaluation of line differences, but no measurements were made between 160 and 450 days in generation eight.

Conclusions

Selection for weight of testes at 150 days of age increased the number of sperm cells produced per day. Differences between lines occurred at ages of 100 to 160 days and were maintained to 450 days. The increase was due mostly to larger testes in select line boars, but was also due to greater efficiency of daily sperm production. Experiments are underway to assess the quantity and quality of semen in boars from these lines.

[1]Tom A. Rathje is a Research Technician and Rodger K. Johnson is a Professor in the Animal Science Department at the University of Nebraska-Lincoln.

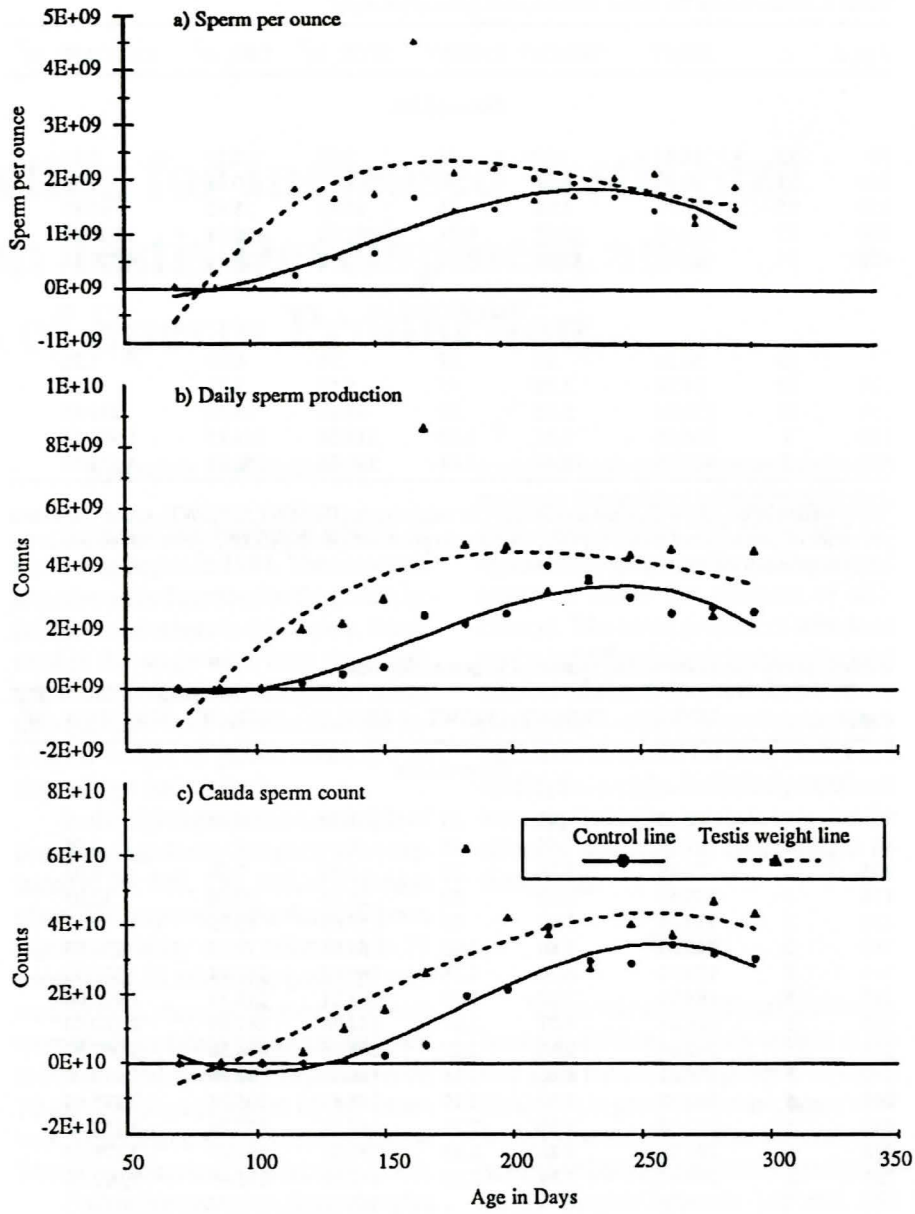


Figure 2. Sperm cell count per ounce of parenchymal tissue (a), sperm cells produced per day (b), and sperm cell count in the epididymis (c). Values are billions of cells, e.g. 4E+9 = 9 billion, 1E+10 = 10 billion.

Breaking The Chain of Swine Dysentery Transmission: Development of a New Diagnostic Test to Identify Carrier Pigs

Gerald E. Duhamel
Robert O. Elder[1]

Swine dysentery results from intestinal infection by the spirochete bacteria, *Serpulina hyodysenteriae*. The disease affects pigs in the growing and finishing stages, and is characterized by severe diarrhea. The feces usually contain mucus and blood, and as a result, the pigs may lose weight, and even die if not cared for properly.

Swine dysentery is controlled by placing antibiotics in the water and (or) feed which are effective against *S. hyodysenteriae*. Although clinical disease can be controlled by treatment with these antimicrobials, persistence of *S. hyodysenteriae* infection, and reinfection after withdrawal of antimicrobials are common. The disease has been reported in every major pig-producing country in the world, and has a significant economic impact on the United States swine industry because of death of pigs, decreased rate of growth, and cost of continuous medication with antimicrobials.

We recently estimated the cost of treatment on midwestern swine farms affected with swine dysentery to be $8.84 per pig going to market. Depopulation, followed by disinfection of facilities and repopulation is often the only alternative for producers who can no longer afford to continue treating pigs. The significance of improved methods to control swine dysentery are therefore readily apparent.

Nine different serotypes of *Serpulina hyodysenteriae* have been recognized worldwide. At least four different serotypes of *S. hyodysenteriae* are present in the United States. The diagnosis of swine dysentery is based on herd history, clinical signs, and observation of characteristic changes in the large intestine. Isolation of *S. hyodysenteriae* from feces or intestine is accomplished using selective culture media containing blood incubated in the absence of oxygen for 2 to 6 days. On this medium, *S. hyodysenteriae* destroys or hemolyses the red blood cells along areas of spirochetal growth. Confirmation of *S. hyodysenteriae* by culture is based upon the appearance of the spirochetal growth and the pattern and intensity of the breakdown of red blood cells by the spirochetes. The problem remains that certain non-pathogenic spirochetes commonly found in feces of pigs have similar growth patterns. As a result, a definitive diagnosis of swine dysentery can be very difficult, particularly when the disease occurs on farms where non-pathogenic spirochetes are also present in the feces of the pigs.

Another important aspect of swine dysentery is that some pigs can continue to transmit the disease even after they recover from diarrhea because they continue to shed low numbers of *S. hyodysenteriae* in their feces. The numbers of spirochetes that these carrier pigs shed is below the detection limits of currently available laboratory isolation procedures (less than 10,000 per gram of feces). As a result, they can escape detection and act as reservoirs of *S. hyodysenteriae* on infected farms and transmit the disease to noninfected farms.

Sensitive and specific methods for rapid identification of *S. hyodysenteriae* in diagnostic specimens are needed. Biotechnology offers a solution to this problem. Amplification of specific DNA sequences by polymerase chain reaction (PCR) provides a highly sensitive and specific tool for direct detection of disease-causing bacteria from feces without the need for culture. In this study, we describe the development of a sensitive and specific PCR test for rapid identification of pigs shedding *S. hyodysenteriae* in their feces.

Procedures and Results

A PCR test to detect *S. hyodysenteriae* in feces was developed based on analysis of a DNA fragment unique to *S. hyodysenteriae*. The DNA fragment was inserted into *Escherichia coli* bacteria, causing the *E. coli* to copy the *S. hyodysenteriae* DNA fragment so it could be analyzed. Preliminary studies indicated that the DNA fragment of *S. hyodysenteriae* inserted into the *E. coli* was present in all the serotypes of *S. hyodysenteriae* present in the United States, but absent from non-pathogenic spirochetes of pigs. These results prompted us to investigate the use of this DNA fragment as a marker for rapid and specific identification of *S. hyodysenteriae* in feces of pigs by PCR.

Several million copies of the *S.*

(Continued on next page)

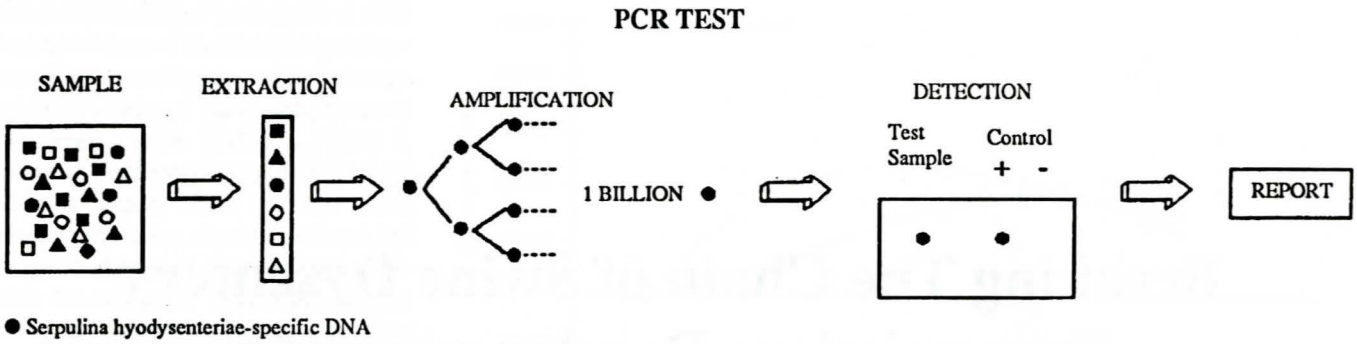


Figure 1. PCR test for detection of pigs infected with swine dysentery.

hyodysenteriae-specific DNA fragment were made by PCR allowing them to be easily detected (Figure 1). When DNA from *S. hyodysenteriae* serotypes 1 through 9, other non-pathogenic spirochetes, and other bacteria normally found in feces of pigs were tested by PCR, positive results were obtained only with the 9 serotypes of *S. hyodysenteriae*. Normal pig feces inoculated with decreasing concentrations of the *S. hyodysenteriae* were examined using the PCR test. With this approach, the sensitivity of the test was calculated to be between 1 and 10 spirochetes per gram of feces. Results of PCR tests with 6 samples of feces and mucosal scrapings obtained from pigs on 4 farms with swine dysentery correlated completely with results of bacteriological culture using selective medium.

Discussion

Detection and identification of *S. hyodysenteriae* has been labor intensive and lacking in sensitivity and specificity. In this report we present the use of a PCR test to detect *S. hyodysenteriae*. We have shown that the PCR test can be applied to direct detection of *S. hyodysenteriae* in diagnostic specimens. Important observations from this data are as follows: (i) the test yielded positive results with all the serotypes of *S. hyodysenteriae* known to infect pigs; (ii) bacteria other than *S. hyodysenteriae*, including closely related non-pathogenic spirochetes, gave negative results; (iii) the sensitivity of the PCR test was between 1 and 10 spirochetes per gram of feces, thus allowing detection of *S. hyodysenteriae*-carrier pigs which are normally undetectable by standard culture methods.

Routine identification of *S. hyodysenteriae* using culture methods is based on the pattern and intensity of hemolysis of red blood cells in the culture medium after 2 to 6 days; however, this characteristic is similar for the non-pathogenic spirochetes and can lead to false-positive diagnosis of swine dysentery. Also, the sensitivity of the culture method depends upon the number of organisms present in the sample, which depends on the stage of the infection of the animal at the time of collection. The numbers of *S. hyodysenteriae* in feces of pigs with bloody diarrhea ranges between 10^6 and 10^{10} per gram of feces. In contrast, carrier pigs may shed recoverable numbers of spirochetes only sporadically and in much lower numbers than pigs with bloody diarrhea. This often results in false negative culture results. Fecal samples from farm cases of swine dysentery also may contain drug residues that adversely affect recovery of viable *S. hyodysenteriae* by bacteriological culture. Factors which affect the results of routine bacteriological culture are not critical to detection of *S. hyodysenteriae* by PCR.

Conclusion

Polymerase chain reaction testing of fecal specimens provides a more rapid and accurate method of obtaining a definitive diagnosis of swine dysentery than culture (1 day for PCR versus 2 to 6 days by culture). Additionally, non-invasive diagnostic procedures, such as PCR tests on feces, do not require euthanasia of sick animals for necropsy or shipping of whole-intestine specimens through courier services. The PCR test will be an invaluable tool for screening newly acquired replacement stock before introduction into susceptible farms. The PCR test may also be useful as a method of identifying carrier pigs in herds that are attempting eradication without depopulation. Investigations aimed at understanding the molecular epidemiology of swine dysentery and the pathogenesis of carrier status in swine dysentery are now possible.

---

[1]Gerald E. Duhamel is an Associate Professor and Robert O. Elder is a graduate assistant in the Department of Veterinary and Biomedical Sciences at the University of Nebraska-Lincoln.

Intestinal Spirochetosis, A Newly Recognized Diarrheal Disease of Growing Pigs

Gerald E. Duhamel
Mohan Ramanathan[1]

Spirochete bacteria commonly found in the intestine and feces of pigs are regarded as part of the normal inhabitants of the gut. However, certain spirochete bacteria are clearly associated with diarrheal diseases of pigs. An example is, *Serpulina hyodysenteriae*, which causes swine dysentery, a contagious disease of pigs characterized by severe and sometimes bloody diarrhea. Other swine intestinal spirochetes, which resemble *S. hyodysenteriae*, are referred to as weakly hemolytic intestinal spirochetes (WHIS) and are assigned to the species, *Serpulina innocens*. These two species are distinguished in laboratory cultures by the amount of breakdown of red blood cells or hemolysis when cultured on medium containing blood; *S. hyodysenteriae* produces a strong hemolysis whereas *S. innocens* is only weakly hemolytic. As the name implies, *S. innocens* are assumed to be harmless; however, this might not be the case for all WHIS. First, numerous reports describe structural, biochemical, and antigenic differences among WHIS isolated from pigs. Additionally, diarrhea associated with WHIS has been reported in animals and humans and the disease has been referred to as intestinal spirochetosis (IS).

The objectives of this work were to report the first confirmed occurrence of IS of pigs in the United States and describe the changes occurring in the intestine of pigs affected with the disease. Also, in a collaborative research project with scientists at the Department of Anaerobic Microbiology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, and the National Animal Disease Center, Ames, Iowa, we compared the WHIS isolated from pigs in the United States and the United Kingdom, with an isolate obtained from a human with acquired immunodeficiency syndrome (AIDS)-associated IS, and the reference strains of *S. hyodysenteriae*, and *S. innocens*.

Results

Pathology: Three live 3- to 4-month-old pigs from a 120-sow breeding herd were submitted because of depression of weight gain and diarrhea without blood. During the past 12 months on this farm, an estimated 80 percent of the pigs from post-weaning to finishing had shown signs of diarrhea and mortality was approximately 20 percent. At necropsy, the most significant changes were chronic pneumonia and abundant watery green intestinal contents with inflammation of the wall of the large intestine. By light microscopy, spirochetes were found intimately attached by one end along the surface of the intestine producing a dark fringe (Figure 1). Rosettes and ribbons of spirochetes tightly joined together in a picket fence fashion were also present in the lumen of the gut (Figure 1). The intestinal glands were dilated and filled with abundant mucus mixed with spirochetes and inflammatory cells were present within the wall of the gut. Ultrastructural examination revealed that the brush border of intestinal cells at the site of attachment by spirochetes was lost and spirochetes had invaded deep into the gut wall.

Microbiology: Weakly hemolytic intestinal spirochetes were isolated from the large intestine of all three pigs. *Salmonella choleraesuis* was also isolated from the intestine of one pig. Genetic analysis of DNA extracted from the American WHIS isolate revealed that it was similar to WHIS associated with IS in swine in the United Kingdom and human beings in the United States. The WHIS from pigs and human beings belongs to a species of spirochetes which is distinct but related to *S. hyodysenteriae* and *S. innocens*. Based on these studies, we identified a new species of spirochete, *S. coli*, which is associated with IS of swine and human beings.

Discussion

Soon after the identification of *Serpulina hyodysenteriae*, scientists recognized the existence of WHIS which were different from *S. hyodysenteriae*. The WHIS were assigned to a new species, *S. innocens*. Concurrently, however, workers in the United Kingdom described a diarrheal disease of growing

(Continued on next page)

Figure 1. Spirochetes intimately attached by one end along the surface of the intestine producing a dark fringe. Also note a rosette of spirochetes in the lumen of the gut.

pigs which was associated with infection by a WHIS. This condition in pigs is associated with attachment of the spirochetes along the gut surface similar to that seen in humans affected with IS. In humans, IS is characterized by chronic diarrhea and rectal bleeding, and the disease has been seen mostly in young children from Africa, India, Middle-East, and amongst Australian aborigines. In Western societies, however, the condition is almost exclusively seen in adults affected with AIDS.

We have used genetic analyses to examine the relationships between WHIS isolated from pigs with IS and other spirochetes from pigs and humans. Our results indicate that the WHIS isolated from pigs in the United States are different from *S. hyodysenteriae* and *S. innocens*, but similar to the strain in the United Kingdom reported to be the cause of IS. Additionally, the WHIS isolates from pigs in the United Kingdom and the United States were indistinguishable from a WHIS associated with human IS. A new species of spirochetes, *S. coli* was proposed for WHIS associated with IS of swine and humans.

These findings are significant because they provide direct evidences of the existence of IS in pigs in the United States. Because of the close genetic relationships between WHIS, it raises the possibility that these organisms may be a zoonotic infection i.e., transmitted between animals and humans. In view of the widespread distribution of IS in people and the existence of a diarrheal disease of pigs which is caused by genetically similar organisms, further study of the disease is warranted.

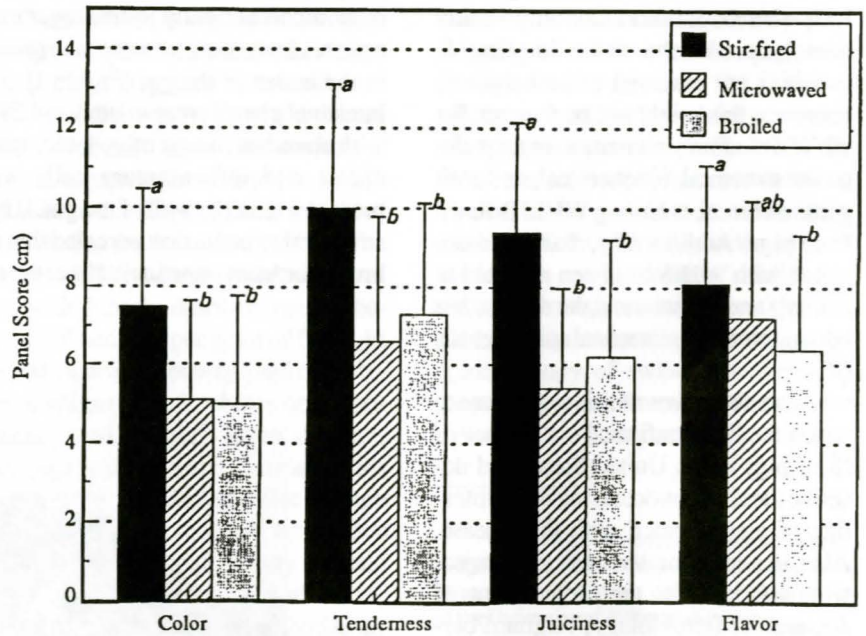
[1]Gerald E. Duhamel is an Associate Professor and Mohan Ramanathan is a graduate assistant in the Department of Veterinary and Biomedical Sciences at the University of Nebraska-Lincoln.

Sensory and Nutritive Qualities of Pork Strips Prepared by Three Household Cooking Techniques

Judy Driskell
Jing Yang[1]

The sensory and nutritive qualities of pork strips prepared by either stir-frying, microwaving, or broiling were evaluated. Stir-frying and microwaving are methods of preparation that are becoming more popular. These are quick and easy methods of preparing food; therefore, products prepared in these ways can be considered as convenience foods.

Fresh pork hams were obtained from two different sources. The hams were cut into 0.2 x 1.0 x 1.6 in strips with no separable fat by the University of Nebraska Meat Laboratory and frozen. After thawing, they were cooked by each method to an internal temperature of 150°F. The strips were cooked in batches representing three servings and different batches of strips were cooked by each method on three different occasions. The cooking times for the three methods

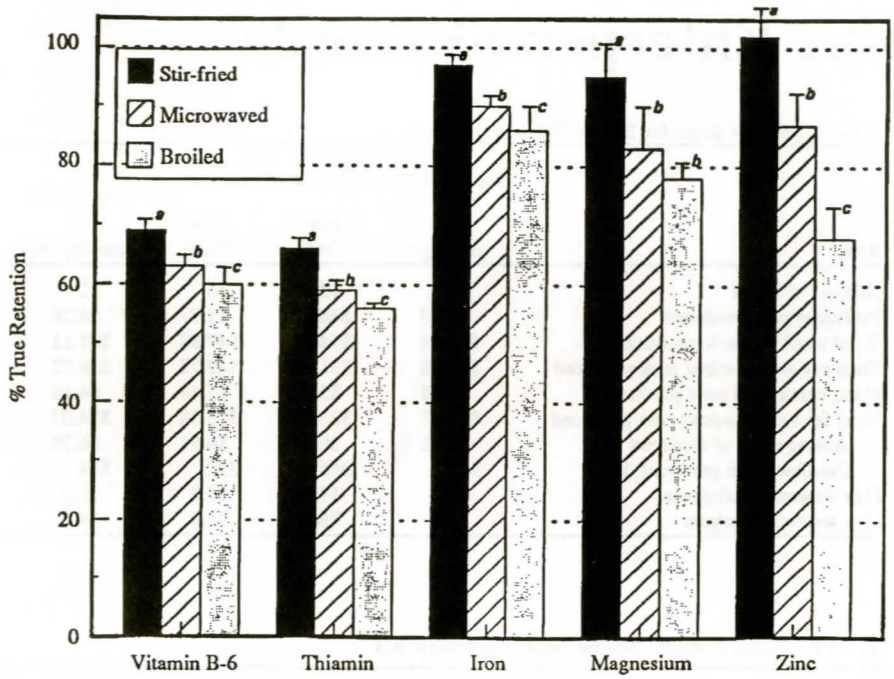


Values represent means ± standard deviations.

[ab]Values for each attribute not sharing a common superscript are significantly different ($p < 0.01$).

Color was scored from 0 = pale, gray to 15 = brown; tenderness, 0 = very tough to 15 = very tender; juiciness, 0 = very dry to 15 = very juicy; and flavor, 0 = absence of flavor to 15 = characteristic flavor.

Figure 1. Sensory Evaluation of Pork Strips Following Three Methods of Cooking as Evaluated by Trained Panel.



Values represent means ± standard deviations.

[abc]Values for each nutrient not sharing a common superscript are significantly different at $p < 0.01$.

Figure 2. True Retention Values of Selected Nutrients in Pork Strips Cooked by Three Different Methods.

ranged from 3 (stir-frying) to 3 1/2 (microwaving) minutes.

A 14-member panel consisting of young men and women was trained as a taste panel. They evaluated the cooked strips for differences in color, flavor, tenderness, and juiciness. The results are shown in Figure 1. Pork strips cooked by stir-frying were significantly browner, more tender, and juicier than those cooked by broiling or microwaving. Strips cooked by stir-frying were significantly more characteristic in flavor than those cooked by broiling, but not microwaving.

Pork cuts are "good" to "major" sources of many nutrients that Americans frequently consume in less than adequate quantities. These nutrients include vitamin B-6, iron, magnesium, and zinc. The amount of these nutrients in the cooked pork strips and their retention values were determined. Thiamin is a vitamin in meat products that is easily destroyed. If there is low retention of thiamin during a cooking process, low retention of other nutrients can also be expected. Therefore, thiamin was considered as an index nutrient. Cooked pork strips (3 ounces or 100 grams) were found to contain approximately 25% of the vitamin B-6, 12% of the iron, 8% of the magnesium, and 23% of the zinc needed to meet the Recommended Dietary Allowances of adults for a day.

The true retention of these vitamins and minerals which were in pork strips cooked by the three methods are given in Figure 2. True retention is a term that relates the percentage of nutrient content of the food as cooked to what it had before cooking. Significantly more vitamin B-6, thiamin, iron, magnesium, and zinc were retained in strips cooked by stir-frying than by the other two methods.

The sensory attributes of pork strips cooked by stir-frying were generally more desirable and they retained a higher percentage of their nutrients than those cooked by microwaving and broiling.

---

[1]Judy Driskell is a Professor and Jing Yang is a graduate student in the Department of Nutritional Science and Dietetics at the University of Nebraska-Lincoln.

1993 Swine Enterprise Records

Dale Kabes
Michael Brumm
Larry Bitney[1]

With another year of growth, the results from cooperators in the Nebraska Swine Enterprise Records Program clearly document the variation in profit between producers for all types of swine enterprises. However, with the unexpectedly strong market prices received for the past year, all groups of producers except the low profit group for feeder pig finishers reported positive profits after all costs were accounted for.

Averages for farrow-finish, farrow-feeder pig and feed pig finishing enterprises for the first six months (January through June) of 1993 are given in Tables 1, 2, and 3. Also included are values for producers who submitted data for the period July, 1992 through June 1993.

In addition to the overall average, each summary has a column which contains the average values for producers that ranked in the high 1/3 for profit and the low 1/3 for profit for the January 1993 through June 1993 period. With corn prices at $2.05/bu for the six-month period ending June 30, 1993 and $2.06/bu for the 12-month period ending June, 1993, the high profit farrow-finish producers reported feed costs under $23/cwt and non-feed costs of less than $13/cwt.

With many producers considering investments in production assets during 1994 (either for expansion or replacement of existing assets), it remains critical that production output (either cwt of gain or feeder pigs) must match the investment. Investment in assets without a corresponding improvement in output dooms a swine enterprise to low profits or failure.

[1]Dale Kabes is swine records coordinator, Michael Brumm is Professor in the Animal Science Department, and Larry Bitney is Professor in Agricultural Economics.

Table 1. Selected items for farrow-finish enterprises.

Item	Jan. 1 - June 30, 1993 Average	High Profit	Low Profit	July 1, 1992 to June 30, 1993
Number of farms	44	15	15	32
Profit/cwt pork produced	$9.50	$16.92	$1.77	$4.26
Total cost/cwt pork produced	**$41.54**	**$34.89**	**$47.68**	**$41.11**
Total variable cost/cwt pork produced	$37.26	$31.36	$42.22	$36.92
Fixed cost/cwt of pork produced	$4.28	$3.53	$5.46	$4.19
Total feed expense/cwt pork produced	$24.22	$22.43	$25.38	$24.07
Average cost of diets/cwt	$6.26	$6.17	$6.51	$6.29
Feed/cwt pork produced, lb	387	365	390	384
Pigs weaned/female/year	17.2	17.9	16.5	16.3
Pigs weaned/crate/year	72.6	76.8	75.5	68.8

Table 2.Selected items for farrow-feeder pig enterprises.

Item	Jan. 1 - June 30, 1993 Average	High Profit	Low Profit	July 1, 1992 to June 30, 1993
Number of farms	14	7	7	14
Profit/cwt pork produced	$18.83	$31.17	$6.50	$8.18
Total cost/cwt pork produced	**$73.49**	**$67.19**	**$79.79**	**$66.22**
Total variable cost/cwt pork produced	$65.59	$59.02	$72.16	$58.60
Fixed Cost/cwt of pork produced	$7.90	$8.17	$7.63	$7.62
Total feed expense/cwt pork produced	$36.40	$33.93	$38.87	$33.08
Average cost of diets/cwt	$8.33	$8.29	$8.37	$8.08
Feed/cwt pork produced, lb	439	410	467	410
Pigs weaned/female/year	16.3	17.4	15.1	16.4
Pigs weaned/crate/year	74.4	84.9	63.8	72.8
Average weight of feeder pig sold, lb	46.7	46.8	46.5	48.5

Table 3. Selected items for feeder pig finishing enterprises.

Item	Jan. 1 - June 30, 1993 Average	High Profit	Low Profit	July 1, 1992 to June 30, 1993
Number of farms	9	4	4	8
Profit/cwt pork produced	$4.47	$9.05	$-.52	$6.63
Total cost/cwt pork produced	**$32.35**	**$28.59**	**$36.56**	**$29.51**
Total variable cost/cwt pork produced	$29.55	$26.97	$32.30	$26.62
Total feed expense/cwt pork produced	$23.09	$20.87	$25.74	$21.04
Average cost of diets/cwt	$6.05	$5.87	$6.18	$5.95
Feed/cwt pork produced, lb	383	356	420	354
Weight of feeder pig purchased, lb	45.2	39.5	50.0	42.4
Price/head of feeder pig purchased	$48.45	$45.52	$51.10	$40.99
Total cost of labor/cwt pork produced	$2.13	$2.01	$2.26	$1.79