1996

1996 Nebraska Swine Report

Duane E. Reese

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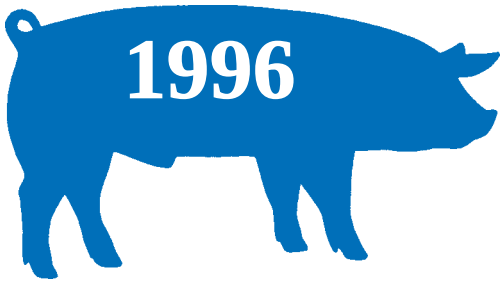

NEBRASKA SWINE REPORT

- Reproduction
- Breeding
- Health
- Nutrition
- Economics
- Housing

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

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The 1996 Nebraska Swine Report was compiled by Duane E. Reese, Associate Professor and Extension Swine Specialist, Animal Science, Department of Animal Science.

Cover Photo:

Determining body composition of live pigs is very important in genetic evaluation. Here, ultrasonic estimates of body composition are being taken as part of the National Swine Improvement Federation Ultrasound Certification Workshops recently held in Nebraska.

Photo courtesy of the ***Beatrice Sun.***

Age and Synchrony of First Estrus in Gilts as Influenced by Type and Duration of Daily Boar Exposure (BE)

Dwane R. Zimmerman
Tom McGargill
Norm Rohda
Jeff Hall[1]

Summary and Implications

Fence-line boar exposure (FBE) and physical boar exposure (PBE), each with durations of 10 minutes or four hours, were evaluated for their ability to trigger puberty in gilts. Gilts provided PBE attained puberty 11.8 days earlier than gilts provided FBE. Duration of boar contact was without effect. Earlier age at first estrus resulted, in large part, from a more rapid pubertal response after initiation of boar exposure (BE). The mean interval from initiation of BE to pubertal estrus was 13.5 days for PBE gilts and 24.8 days for FBE gilts. Fence-line boar exposure stimulates earlier puberty in gilts (shown in previous studies), but is less effective than PBE for triggering a rapid pubertal response in gilts. Physical boar exposure is required to achieve the maximal pubertal response to boar exposure when applied daily for limited periods (4 hours or less) to gilts nearing onset of puberty.

Introduction

Recent evidence from Australia suggests that physical contact with boars is needed to achieve the maximal pubertal response in gilts. Fence-line contact with boars or providing gilts contact with a caged boar were less effective than full-contact with boars. Further, gilts that were masked and prevented from having nose-to-nose contact with boars were less responsive to full-boar contact than unmasked control gilts. Duration of contact may also be important.

Research conducted at Nebraska (1994 Nebraska Swine Report) determined that once daily (10 min/day) physical contact with boars was less effective than either continuous fence-line or continuous physical contact with boars. However, earlier research at Nebraska (1988 and 1991 Nebraska Swine Reports) demonstrated that duration of boar exposure (BE) was without effect when duration was relatively short. No difference was observed between 5, 15 and 30 minutes of once daily BE. The objectives of the present experiment were to determine the effects on the pubertal response in gilts of: (1) type of BE, physical vs fence-line contact with boars; (2) duration of BE, 10 minutes vs four hours of daily contact with boars, and (3) the possible interaction of type of BE and duration of BE.

Materials and Methods

Fifty-six gilts from the Gene Pool herd were assigned randomly within litter to a replicated experiment involving two types of boar exposure (physical contact, PBE vs fence-line contact, FBE) and two durations of daily BE (10 min vs 4 hours). Blood samples were obtained for later analysis of progesterone one week before and one day before initiation of treatment on December 16, 1994 (age = 172 to 177 days, Rep 1 and 164 to 175 days, Rep 2) to establish ovarian status. Gilts were maintained in groups of seven or eight in a separate room from where they received BE. Each group of gilts was taken to the boar room for the assigned period of BE each day.

Two sets of four crossbred boars (7 to 8 months of age at start) were used. They were maintained in separate pens between periods of BE and rotated between treatment groups each day to insure that PBE and FBE gilts received similar boar stimuli during the treatment period. Physical BE was provided by moving two boars into each of

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Table 1. Mean (± SE) age at puberty as affected by type and duration of boar exposure (BE)

	Duration of BE		
Type of BE[a]	10 min	4 h	Combined
FBE	199.4 ± 5.5	198.3 ± 4.5	198.8[b]
PBE	186.9 ± 4.5	187.0 ± 4.8	187.0
Combined	193.2	192.6	

[a]FBE, fence-line contact with boars; PBE, physical contact with boars.
[b]P<.02

Table 2. Mean (± SE) interval to puberty after initiation of boar exposure (BE)

	Duration of BE		
Type of BE[a]	10 min	4 h	Combined
FBE	25.7 ± 5.2	24.0 ± 4.3	24.8[b]
PBE	13.6 ± 4.3	13.4 ± 4.5	13.5
Combined	19.6	18.7	

[a]FBE, fence-line contact with boars; PBE, physical contact with boars.
[b]P<.05

two gilt pens maintained for the PBE treatment. Fence-line BE was provided by moving FBE gilts into pens on each side of a pen occupied by four boars. Each group of gilts was returned to their home room after the assigned treatment period (10 min or 4 hours). Gilts were observed and symptoms of estrus recorded for all groups during the first 10 minutes of BE each day. Any gilts on the PBE treatment that were observed in estrus were removed immediately from the pen and returned to their home room to prevent mating and encourage boars to continue stimulating other gilts in the pen. Gilts exposed to boars for four hours were observed again for estrus just before (5 min) they were returned to their home room.

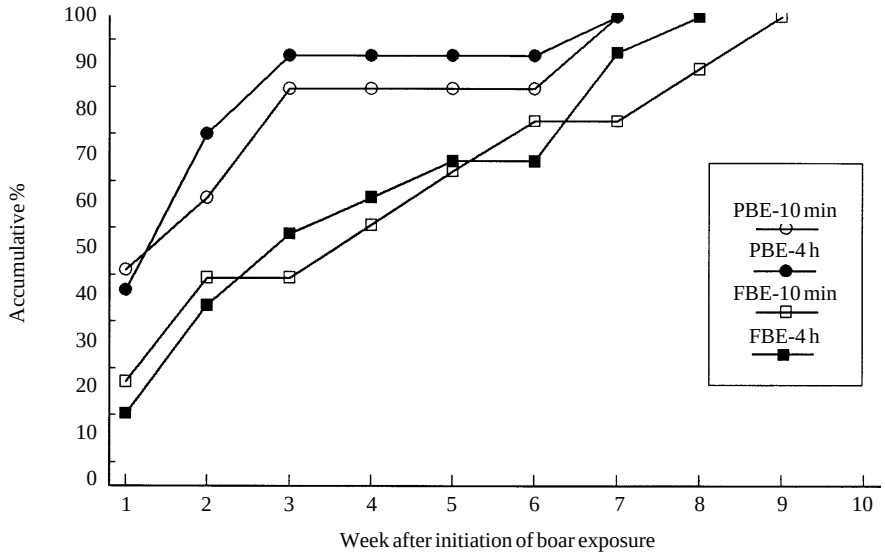

Figure 1. Accumulative percentage of gilts expressing pubertal estrus after initiation of boar exposure. FBE = fence-line contact with boars and PBE = physical contact with boars.

Results and Discussion

Seven gilts had ovulated before treatment initiation and were deleted. Two other gilts were deleted because of lameness or their reproductive tract was missing. All other gilts (N=47) expressed first estrus by termination of the experiment on February 13. Type of BE but not duration of BE produced a significant difference in average age at puberty. No interaction was observed between type and duration of BE. Gilts that received PBE reached puberty 11.8 d earlier than gilts that received FBE (187.0 vs 198.8, P<.02, Table 1). The interval to first estrus after initiation of BE was substantially shorter (13.5 vs 24.8 d, P<.05, Table 2) in PBE gilts. This resulted in part because PBE gilts showed a more synchronous first estrus. Forty-four percent of PBE gilts vs 18 percent of FBE gilts expressed first estrus at the end of the first week of BE (Figure 1). The advantage widened at the end of the third week of BE (88% PBE vs 50% of FBE gilts had reached puberty) and then declined gradually thereafter. All PBE gilts had expressed first estrus by the end of wk 7 of BE. FBE gilts did not achieve a 100 percent pubertal response until the end of the 9th week.

Physical BE is a more effective stimulus than FBE for triggering an earlier and more synchronous first estrus in gilts nearing puberty when first stimulated. Future experiments will attempt to determine the reasons for this difference and whether this difference is expressed when boar exposure is applied at earlier stages of pubertal development.

[1]Dwane R. Zimmerman is a Professor, Tom McGargill and Norm Rohda are Research Technicians and Jeff Hall is an undergraduate student in the Animal Science Department.

Is Physical Boar Exposure Required for Accurate Detection of Estrus in Gilts?

Dwane R. Zimmerman
Denny Aherin
Jeff Hall[1]

Summary and Implications

Accuracy of estrus detection in response to physical (PBE) vs fence-line (FBE) boar exposure was evaluated in 40 gilts during two successive estrous periods. Gilts heat checked with FBE expressed shorter estrous periods (.6 day) than PBE gilts. Estrus was detected within five minutes of boar exposure in 100 percent of gilts on both treatments except for PBE gilts on the first day of estrus. The first day of estrus was expressed after five minutes of boar exposure in 16.2 percent of PBE vs 0 percent of FBE gilts. The PBE gilts may be near the beginning of estrus. They are unresponsive to limited (15 min) FBE and slow to respond to PBE. Fertility was not compared in this study, but inseminations timed 12 to 24 hours after detection of estrus in these gilts (gilts not detected with FBE and slow to respond to PBE on their first day of estrus) will be too late to result in high fertility. Ovulation will occur or be in progress in these gilts at the time of insemination. Therefore, heat-detection with physical boar exposure rather than fence-line boar exposure is recommended to achieve proper timing of insemination and high fertility in gilts.

Introduction

Accurate heat detection is needed with hand mating and artificial insemination (AI) programs to insure optimum timing of the inseminations relative to ovulation. Proper timing of the insemination, especially with AI, minimizes loss of potential piglets (ova) caused by fertilization failure and/or early embryonic death. Heat detection is labor intensive and should be organized so gilts in heat express the immobility reflex rapidly when exposed to the boar. Gilts should be maintained in pens segregated from boars or boar stimuli and taken to a neutral area or the boar room to receive boar exposure during the heat check period. Most estrous gilts handled in this manner respond rapidly (>90% within 5 min) to physical contact with boars. Little advantage is gained from extending the period of heat detection beyond 10 minutes of boar exposure.

Classical research conducted by Signoret and co-workers in France during the late fifties and early sixties demonstrated that only 50 percent of gilts in estrus express the immobility reflex in response to tactile stimulus (hand pressure) applied by the observer in the absence of boars. The estrous response exceeded 90 percent when the gilts were provided olfactory (smell) and auditory (sound) stimuli from a mature boar across the fence-line but the gilts were unable to touch or see the boar. Recently, studies from Australia and Nebraska evaluated the effects of type and/or duration of boar exposure (physical, PBE vs fence-line, FBE) on pubertal development in gilts. Limited PBE was more effective than limited FBE (each applied for 10 to 30 minutes once daily) for triggering pubertal estrus in gilts. The difference may be due to better transfer of pheromones or to the tactile stimulus of the boar. Alternatively, boars under these conditions (direct contact between the boar and gilts) may provide greater auditory and/or olfactory stimuli than boars not allowed to interact directly with females.

The objectives of the present experiment were to determine, under conditions of limited boar exposure (15 min once daily), whether (1) physical contact with boars results in a higher rate of estrus detection and more rapid expression of the immobility response than fence-line boar exposure and (2) whether type of boar exposure affects the number of days gilts are observed in estrus. Estrous gilts that are slower to respond to boar stimuli may not be detected in heat until their second day of estrus under conditions of limited boar exposure each day.

Materials and Methods

Forty gilts with established estrous cycles (2 or more) from the Gene Pool herd were grouped according to their last estrus in pens of four gilts

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each. Pens of gilts were assigned randomly to receive either physical contact with a boar (PBE) or fence-line contact with boars (FBE) during a standardized period (15 min) of boar exposure between 7 and 9 a.m. each day. Following completion of estrous observations on all forty gilts, the treatment assignment was reversed and the gilts were evaluated again at the next estrus using the same procedures.

Heat checks were initiated when the first gilt(s) in the pen reached d 17 of the estrous cycle and ended when the last estrous gilt in the pen was out of estrus. Gilts were housed in rooms segregated from boars and were taken to the boar room for heat checking. During the first five minutes of the heat check, symptoms of estrus, including the immobility response to back pressure, were observed and recorded for each gilt. Gilts were removed from the heat check pen as they expressed standing heat and the time of expression of estrus was recorded. The boars and FBE gilts were kept in close contact on the fence-line and continued to be checked by hand during the remainder of the 15 minute test. Two boars (11 to 12 mo of age) were used to stimulate estrus. Gilts receiving PBE were placed directly in the pen with each boar on an alternate day basis.

Table 1. Mean number of days gilts were observed in estrus.

Estrous period	PBE[a]	FBE[b]	Difference
Number of gilts	19	18	
First	3.0	2.4	.6
Second	3.1	2.5	.6
Combined	3.05	2.45	.6[c]

[a]Physical contact with boars.
[b]Fence-line contact with boars.
[c] P<.01

Gilts provided FBE were placed in a pen between the two boar pens and had the opportunity for boar contact, including naso-naso contact through open vertical bars (4-inch spacing) along each 10-ft fence-line. Each gilt was evaluated for rapidity of estrous response and for number of days detected in estrus.

Results and Discussion

One gilt failed to express estrus during either the first or second series of estrous checks and a second gilt (FBE) failed to express estrus during the second series of estrous observations. These gilts were deleted from the study. The rate of heat detection was comparable in PBE and FBE gilts. However, gilts heat-detected with PBE expressed estrus approximately .6 d longer than gilts heat-detected with FBE (3.05 vs 2.45 days, P<.01, Table 1). This resulted from a shift in the distribution of the percentages of gilts observed in estrus for 1, 2, 3 or 4 days (Figure 1). Few gilts on either treatment were observed in estrus for only one day (2.7% PBE vs 5.4% FBE, P>.1). The percentage of gilts expressing estrus for two days was much higher in FBE than in PBE gilts (48.6 vs 13.5%, P<.01) but the reverse tended to be true for gilts expressing estrus for three days (PBE, 62.2 vs FBE, 43.2%, P>.05). The percentage of gilts observed in estrus for four days was substantially higher (7-fold) in PBE gilts (21.6 vs 2.7%, P<.05).

The distribution of times within the 15-minute heat check period (<5 min, 6 to 10 min or 11 to 15 min) when the first day of estrus was detected also differed between the PBE and FBE treatments. Estrus was detected during the first five minutes in all (100%) FBE gilts compared to 83.8 percent of PBE gilts. The gilts that responded to PBE after 5 min (16.2%) may represent gilts near the beginning of estrus. They may be unresponsive to limited (15 min) FBE and are slow to respond to PBE. All PBE gilts (100%) were detected in estrus within five minutes on the other days of their estrous period. Inseminations timed 12 to 24 hours after first detection of estrus in these gilts (gilts not detected in estrus with FBE on their first day of estrus) would be too late for optimal fertility. These gilts probably already ovulated or are ovulating at the time of insemination. Further research is needed to evaluate ovulation time and fertility in gilts that are unresponsive to FBE and slow to respond to PBE on the first day of estrus.

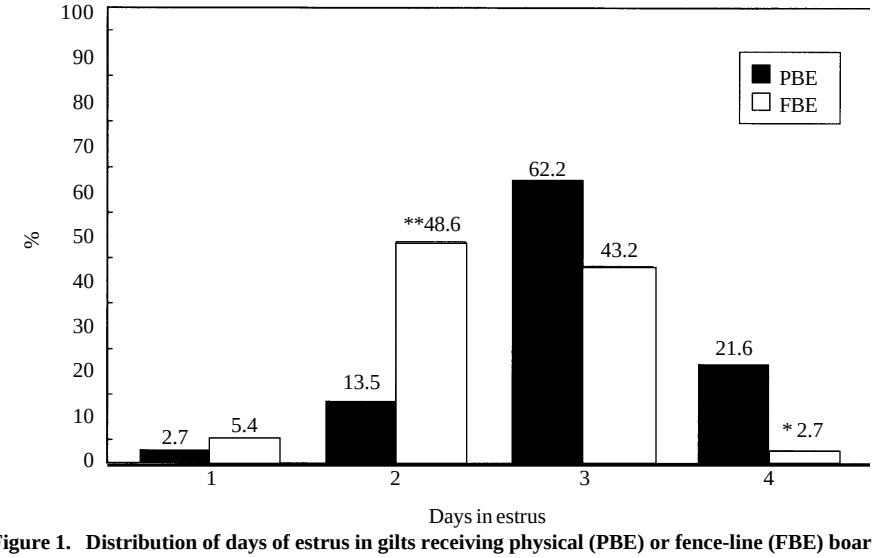

Figure 1. Distribution of days of estrus in gilts receiving physical (PBE) or fence-line (FBE) boar exposure (*P<.05; **P<.01).

[1]Dwane R. Zimmerman is a Professor, Denny Aherin is a Research Technologist and Jeff Hall is an undergraduate student in the Animal Science Department.

The Effect of Photoperiod on Sexual Development in Young Boars

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Summary and Implications

The effects of photoperiod in stimulating reproductive function in prepubertal boars was studied in 40 crossbred boars. One group of boars was exposed to a regimen where day length was increased from 12 to 14.5 h/d (from 8 to 20 weeks of age) and then decreased from 14.5 to 12 h/d (from 20 to 32 weeks of age); whereas, the other group of boars was exposed to a regimen where day length was decreased from 12 to 9.5 h/d and then increased from 9.5 to 12 h/d. Exposing prepubertal boars to a long photoperiod inhibited the development of the testis at 24 weeks of age. The inhibitory effect of long days on testis development at 24 weeks of age was overcome by decreasing the photoperiod. Short days reduced the level of sexual behavior at 25 and 26 weeks of age. The inhibitory effects of short days on sexual behavior was overcome by exposing boars to a longer period. This study implies that young boars reared during short days may need to be exposed to a longer photoperiod before expressing an adequate level of sexual behavior and young boars reared during long days may need to be exposed to shorter days to increase their sperm production capability.

Introduction

The role of photoperiod on reproduction in the male pig has been largely ignored. Most males destined for breeding are reared in some kind of testing facility, but the photoperiod regimen employed in the rearing area is rarely, if ever, considered. There is some evidence to suggest that long day length is inhibitory to steroid synthesis, sperm production and sexual behavior in mature boars but the effect of photoperiod on pubertal development in young boars is less clear. In general, reproductive performance of boars reared in a constant long-day of 15 hours of light has not been different from boars reared on a constant short-day of 8 hours of light. However, the effect of a step-wise light regimen that simulates a natural photoperiod over time on sexual development and behavior has not been studied in male pigs. In this experiment we examined the effect of two step-wise photoperiod regimens during rearing on the sexual and behavioral development of young boars.

Materials and Methods

A controlled-environment building with two similar rooms, each containing four pens was used in this experiment at the Western Australian Department of Agriculture Medina Research Center. Light in both rooms was provided by eight fluorescent tubes and the average light intensity 15.6 inches above the floor was 270 lux. Temperature was maintained as close as possible to 73.4°F in both rooms.

Two light regimens were created by providing different light:dark ratios in each room (Figure 1). At the start of the experiment, boars in both rooms received 12 hours of light and 12 hours of dark (12L:12D) with lights on at 6:00 a.m. and off at 6:00 p.m. In the long-day (LD) regimen the light phase was increased by 15 minutes per week for six weeks then by 10 minutes per week for a further six weeks to give a maximum light:dark ratio of 14.5L:9.5D in the week of summer solstice (longest day length). In the short-day (SD) regimen the light phase was decreased by 15 minutes per week for six weeks then by 10 minutes per week for a further six weeks to give a minimum light:dark ratio of 9.5L:14.5D in the week of the summer solstice. Afterwards, day length was increased (short-day) or decreased (long-day) by 10 minutes per week for six weeks and 15 minutes per week for a further six

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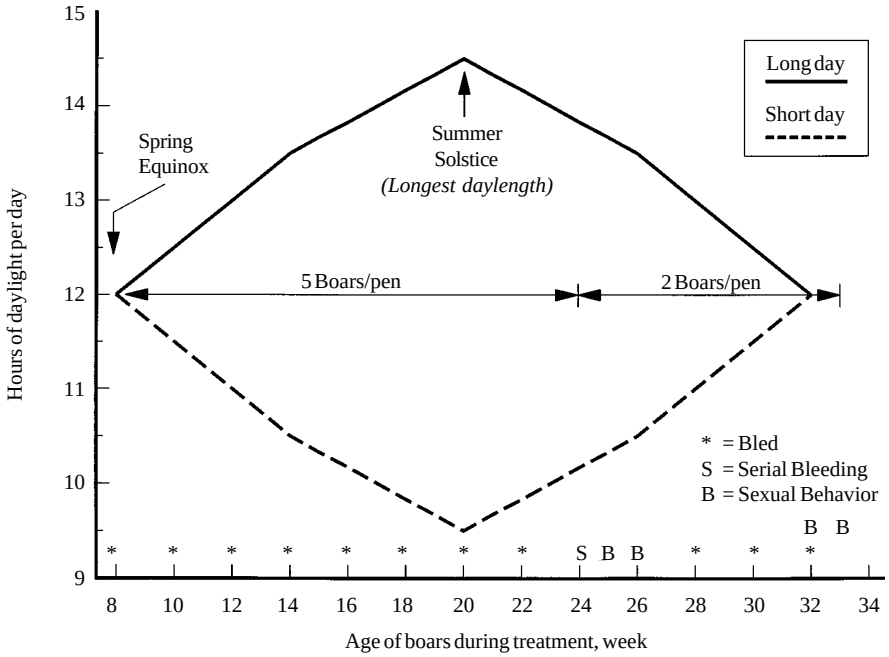

Figure 1. Light regimens and protocol for blood sampling and sexual behavior evaluations for long- and short-day treatments.

weeks so that the light:dark ratio returned to 12L:12D at the end of the experiment.

A total of 40 Large White x Landrace boars were reared together from weaning under natural daylight until transfer to the controlled environment rooms at an average age and weight of 56 ± 5 days and 43.3 ± .7 lb, respectively. There were four pens per room with five boars per pen. The experiment started when natural light:dark ratio was 12L:12D (spring equinox). The boars were weighed and blood sampled every two weeks from eight until 24 weeks of age. At 24 weeks of age three boars from each pen were removed from the controlled-environment rooms. The boars were removed to: (1) prevent damage to the indwelling catheters that were surgically inserted into the jugular vein of two boars in each pen, (2) prevent physical interaction between boars in a pen on the day sexual behavior was evaluated, and (3) to avoid overcrowding during the remaining weeks of the experiment.

During the time when the catheters were inserted in the eight boars, the size of testicles was measured using calipers. Total testicular volume was estimated from the formula for a right ellipsoid ($4/3\ \pi\ h\ r^2$, where $\pi = 3.14$, h = height, and r^2 = radius squared).

Boars were evaluated for sexual behavior at 6 and 7.5 months of age. During the 10-min (600 seconds) sexual behavior tests when the boar had direct contact with an estrous gilt, the following sexual behavior traits were recorded to the nearest second: nosing head area of gilt (DNH), nosing side and flank area of gilt (DNS), nosing ano-genital area of gilt (DAG), time to first mount (TFM), time to first extension of penis, duration of mounts without penis exposed (DMNP), duration of mounts with penis exposed (DMWP), time to first intromission (TI), and duration of copulation. Number of mounts and copulations were also recorded. A sexual behavior index score (SBI) was calculated for each boar by the following formula: SBI = (600 - TFM) + DNH + DAG + (2 x DNS) + DMNP + (3 x DMWP) + [5 x (600 - TI) ÷ 600)]. The boars were not given assistance with copulation. Estrous gilts were prepared by priming prepubertal gilts about 170 to 190 days of age with 1.2 mg of estradiol benzoate four to five days before the behavior testing of boars.

The testicles were collected at slaughter to estimate daily sperm production. The right epididymis and testis were separated and weighed. Three samples of one gram each from the proximal, mid, and distal regions of the testis were used to determine daily sperm production. The three grams of tissue were homogenized and the number of homogenization resistant sperm nuclei was counted in duplicate for each sample with a hemacytometer.

Results and Discussion

Average daily gain and average concentration of testosterone from 8 to 24 weeks of age were not different between the two photoperiod regimens (average daily gain: LD, 1.85 lb/d and SD, 1.98 lb/d; average testosterone concentration: LD, 3.9 ng/mL and SD, 4.4 ng/mL). The following results are only for the 16 boars that remained in the controlled-environment rooms until 33 weeks of age. The average concentration of testosterone in SD boars increased ($P < .01$) from 3.3 ng/mL at 24 weeks of age to 8.1 and 12.7 ng/mL at 28 and 30 weeks of age; whereas, in the LD boars the concentration of testosterone changed less dramatically from 3.7 ng/mL at 24 weeks of age to 5.7 ng/mL and 6.9 ng/mL at 28 and 30 weeks of age. Testosterone concentration differed ($P < .05$) between treatments at 30 weeks of age.

Testis volume was larger in SD than LD boars at 24 weeks of age (Table 1). At 33 weeks of age the SD boars had numerically but not statistically greater average values than LD boars for testes weight, sperm per gram of testis, and total sperm per testis.

The sexual behavior traits of boars at weeks 25 and 26 of age are illustrated in Table 2. Boars kept in the long-day photoperiod regimen mounted more ($P<.02$) times than did boars kept in the short-day photoperiod. The LD boars also tended ($P < .07$) to spend a greater sum of time courting gilts and being mounted on gilts than SD boars, thus LD boars tended ($P < .06$) to have higher SBI scores than SD boars. Although SD boars tended to have larger testis and a greater concentration of testosterone, we speculate that the higher level of sexual activity in LD boars is due to their having more daylight hours to mount, ride and interact with each other. It was noted that when the lights went off, the SD boars soon laid down to sleep.

The main reasons why the boars did not copulate during the mating tests at 25 and 26 weeks of age were

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Table 1. Comparison of testicular characteristics of boars reared in either a long- or short-day photoperiod regimen (mean ± SE)

Item	Treatment		P[c]
	Long day[a]	Short day[b]	
Age at measurement, wk	24	24	
No. of boars	8	8	
Testis volume, cm^3/lb BW	3.58	5.64	.01
Age at slaughter, wk	33	33	
No. of boars	8	8	
Body wt, lb	368 ± 4.6	365 ± 12.8	
Epididymal wt, g	126 ± 8.3	122 ± 5.3	.71
Testis wt, g	512 ± 47.0	547 ± 31.0	.53
Sperm/g testis, 10^6	115.24 ± 6.1	132.19 ± 10.2	.18
Total sperm/testis, 10^{10}	5.85 ± .6	7.08 ± .3	.08

[a]Long day = increasing from 12 h to 14.5 h day length from 8 to 20 wks of age then decreasing from 14.5 h to 12 h day length from 20 to 32 wks of age.
[b]Short day = decreasing from 12 to 9.5 h day length from 8 to 20 wks of age then increasing from 9.5 to 12 h day length from 20 to 32 wks of age.
[c]P = probability of difference between light regimens.

Table 2. Comparison of sexual behavior traits of boars reared in either a long- or short-day photoperiod regimen (eight boars per treatment)

	Sexual behavior test				Probability	
Item	1	2	3	4	LD vs SD[a]	Time
Age at evaluation, wk	25	25	26	26		
Sum of all time spent courting and mounted, sec						
Long-day boars	154.4	219.3	193.5	194.4	.07	.20
Short-day boars	92.9	121.6	89.5	128.3		
Number of mounts						
Long-day boars	3.9	7.5	5.6	6.3	.02	.07
Short-day boars	.5	.9	.6	1.3		
SBI score[b]						
Long-day boars	.74	1.16	1.19	1.12	.06	.04
Short-day boars	.32	.52	.37	.57		
Proportion of tests with a copulation						
Long-day boars	0 (37.5)[c]	0 (62.5)	0 (62.5)	0 (62.5)		
Short-day boars	0 (12.5)	0 (12.5)	0 (12.5	0 (25.0)		

[a]LD = long day and SD = short day.
[b]Sexual behavior index (see text for details).
[c]Proportion of boars mounting.

Table 3. Comparison of sexual behavior traits of boars reared in either a long- or short-day photoperiod regimen (eight boars per treatment)

	Sexual behavior test				Probability	
Item	1	2	3	4	LD vs SD[a]	Time
Age at evaluation, wk	32	32	33	33		
Sum of all time spent courting and mounted, sec						
Long-day boars	170.0	170.1	290.9	341.9	.72	.01
Short-day boars	147.4	196.9	274.9	272.1		
No. of mounts						
Long-day boars	5.4	4.4	7.8	2.8	.45	.21
Short-day boars	2.0	3.3	4.4	4.7		
SBI score[b]						
Long-day boars	1.00	.82	2.29	2.45	.29	.03
Short-day boars	.75	1.31	1.23	1.10		
Proportion of tests with a copulation						
Long-day boars	0	0	25.0	37.5[c]		
Short-day boars	0	0	12.5	0		

[a]LD = long day and SD = short day.
[b]Sexual behavior index (see text for details).
[c]Copulation rate was greater (P < .05) for LD boars at the fourth evaluation.

that SD boars expressed a very low level of mounting behavior and LD boars lacked mating dexterity. Since the LD boars did mount the rear of the gilt for an average of 59.6 $\pm$ 11.9 seconds, they probably would have mated if given assistance with copulation. It is not uncommon to see young, inexperienced boars have difficulty with intromission. The average duration of time the two SD boars were mounted on the rear of the gilt was 79.6 $\pm$ 36.7 seconds.

The detrimental effects of short days on sexual behavior at 25 and 26 weeks of age were not observed when the boars were 32 and 33 weeks of age (Table 3). There was no difference at 32 and 33 weeks in the sum of all time spent courting and mounted, number of mounts, or sexual behavior index score. There was no difference in the proportion of tests with a copulation between SD and LD boars during sexual behavior tests 1, 2, or 3. However, LD boars copulated more (P<.05) times during the fourth evaluation.

Plasma FSH Concentration in Young Boars and Gilts from Lines that Differ in Ovulation Rate and Litter Size

Rodger Johnson
Joe Cassady[1]

Summary and Implications

Four experiments were conducted to determine whether boars and gilts from selected lines that differ in ovulation rate and litter size also differ in plasma concentrations of Follicle Stimulating Hormone (FSH). Plasma FSH was studied because it is a potential indicator trait of ovulation rate. Plasma concentrations of FSH in young boars and gilts differed between the select and the control line. It is likely that this difference is due to a correlated response to selection for ovulation rate. Therefore, plasma concentration of FSH in young boars and gilts may be a trait that can be used effectively to indirectly select for ovulation rate. Additional data to more precisely estimate the genetic relationships are needed before selection for FSH is recommended.

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Introduction

One Nebraska research focus has been to identify methods to enhance the rate of response to selection for litter size. The industry practice is to select replacement boars and gilts based on litter size records of the dam and other female relatives. But based on results of our research and that done at the USDA Meat Animal Research Center (MARC), greater rate of response will occur if selection is for ovulation rate and uterine capacity.

Litter size at birth is modeled as the minimum value of the number of viable eggs ovulated and the capacity of the uterus to carry fetuses to parturition. In some females, the number of eggs ovulated is less than uterine capacity and ovulation rate limits litter size. In other females, ovulation rate is greater than uterine capacity, and the number of pigs at parturition equals the number of fetuses the uterus can support. In these females uterine capacity limits litter size.

According to the model, response in litter size to selection for ovulation rate and uterine capacity exceeds response from direct selection for litter size. This kind of selection is done experimentally by measuring ovulation rate with the techniques of laparotomy or laparoscopy. By knowing both ovulation rate and litter size, selection is for the optimum combination of the two traits. However, methods to measure ovulation rate are not practical in industry herds.

A further limitation of current practices of selection for litter size is that there is no direct measure of litter size in males. Boars are selected based on records of dams and sibs. Male selection contributes more to rate of response than female selection because intensity of selection is greater in males. However, to fully realize the increased response the trait must be measured directly in males.

Selection for ovulation rate and uterine capacity could be practiced more easily if a trait that accurately predicts ovulation rate could be measured in both boars and gilts at a young age. Selection for the indicator trait would increase ovulation rate and selection for litter size would increase uterine capacity. Traits would be weighted to maximize the response in litter size.

Follicle Stimulating Hormone (FSH) is a potential indicator of ovulation rate. This hormone stimulates development of follicles that eventually ovulate in females and stimulates development of sperm cells in males. We were encouraged regarding the potential of plasma FSH as a useful predictor of ovulation rate, especially in boars, by results of experiments at MARC. Boars of the Chinese Meishan breed had considerably greater concentrations of FSH in their plasma than did boars of a composite population of Large White, Landrace, Yorkshire, and Chester White. These populations differ greatly in litter size. A major component of this difference is the greater ovulation rate of the Meishan.

The objective of the experiments reported herein was to determine whether boars and gilts from lines that differ in ovulation rate, number of fetuses, and litter size at birth also differ in concentrations of plasma FSH. Four experiments, three with boars and one with gilts, were done. Blood samples were collected over a range of ages because the optimum age at which to sample was not known.

Methods

Pigs were from a select (line I) and a control (line C) line established from a cross of Large White and Landrace. Line I was selected 10 generations for an index of increased ovulation rate and increased embryonic survival to 50 days of gestation. Line C was selected randomly. After 10 generations, gilts of line I averaged 6.7 more eggs ovulated, 3.3 more fetuses at 50 days of gestation, and 3.1 more fully formed pigs at birth than gilts of line C. Index selection ended at the 10th generation. After that there was one generation of random selection and then selection was for increased litter size in line I. Selection continued to be random in line C. Pigs for this experiment were from generations 12 and 13.

Experiment 1. Boars from generation 12 were used. They were randomly selected when they were 56 days of age (1 per litter, 4 from each of 15 half-sib families) from line I (n = 61) or line C (n = 60). They were placed in a modified open front building with 10 pigs per pen. *Ad libitum* access to feed was provided. A blood sample was taken from each boar at 90, 120, and 150 days of age. These ages were chosen because they span the interval during which boars reach puberty. Testis growth is rapid and boars achieve the ability to produce sperm cells during this period.

Experiment 2. Boars used in this experiment also were from generation 12, but they were the replacement boars that had been selected to be breeders. Selection was random in line C and included one boar of each of 15 half-sib families. Boars from line I included one boar from each of the 14 largest litters. There was a total of 60 line I litters. Because boars were selected on their dam's litter size record, and not on any trait measured on them, they represent progeny of an additional generation of selection. This additional generation should enhance the ability to detect a response in plasma FSH to selection for litter size. These boars were raised in the same building as boars described in Experiment 1 until they were approximately 200 d of age. They were then moved to the breeding area, where they were housed in crates. Boars began mating when they were 225 to 250 days of age. A single blood sample from each boar was taken at approximately 11 months of age to study line differences in boars that were more mature than those used in Experiment 1.

Experiment 3. Boars for this experiment were from generation 13. They were the replacement boars selected to be breeders. The selection criteria were the same as described for Experiment 2. However, two boars, a primary breeder and an alternate, were selected from each of the 15 half-sib families of

line C. Two boars from each of the 14 largest litters of line I were selected. A single blood sample was drawn from each boar at 150, 180, and 210 days of age. These ages were chosen because they are intermediate to those used in Experiments 1 and 2.

Experiment 4. Gilts were used in this experiment. They came from generation 12. One gilt was randomly selected from each litter (n = 45, line I; n = 35, line C). At 56 days of age they were placed in a modified open front building with 10 pigs per pen. They were allowed ad libitum access to feed. A blood sample was drawn from each gilt at 50, 90, and 130 days of age. The gilts were prepubertal. Plasma FSH has a characteristic curve during the estrous cycle. By sampling prepubertal gilts, it was not necessary to time the sampling relative to day of estrus. However, plasma FSH is pulsatile in prepubertal gilts. This pulsatility increases variation among gilts when only one sample is taken but does not bias mean differences between lines.

Concentration of FSH in plasma of each blood sample was determined by radioimmunoassay procedures. Data were fitted to appropriate statistical models that accounted for the random effects of half-sib families and the effects of line. Age at time of sampling and the interaction of age with line were also fitted to data from Experiments 1, 3, and 4.

Table 1. Plasma concentrations, mean ± SE (ng/mL), of FSH in boars.

	Line I[a]		Line C[b]		
Age, d	n	Mean	n	Mean	Difference
		Experiment 1			
90	59	71 ± 3	60	66 ± 3	5 ± 4
120	60	89 ± 5	60	75 ± 5	14 ± 7*
150	55	111 ± 7	60	81 ± 7	31 ± 10**
		Experiment 2			
330	14	206 ± 33	15	155 ± 32	51 ± 46
		Experiment 3			
150	30	139 ± 16	28	136 ± 16	4 ± 23
180	29	150 ± 23	28	131 ± 23	20 ± 32
210	30	146 ± 14	28	128 ± 14	18 ± 20

[a]Selected for index of increased ovulation rate and embryonic survival.
[b]Selected randomly.
* P < .05
**P < .01

Table 2. Plasma concentrations, mean ± SE (ng/mL), of FSH in gilts in experiment 4.

	Line I[a]		Line C[b]		
Age, d	n	Mean	n	Mean	Difference
50	45	1016 ± 36	35	814 ± 41	203 ± 54**
90	42	997 ± 37	35	783 ± 41	214 ± 55**
130	41	542 ± 38	35	441 ± 41	101 ± 55†

[a]Selected for index of increased ovulation rate and embryonic survival.
[b]Selected randomly.
† P < .10
**P < .01

Results and Discussion

Boars. Boars of line I had greater concentrations of plasma FSH than line C boars at each age (Table 1). Line x age interactions were not significant in either Experiment 1 or 3. The line differences were significant only at 120 (P < .05) and 150 (P < .01) days of age in experiment 1. Line differences were greatest in the more mature boars used in Experiment 2. However, the differences were not significant because the sample size was small. Results for Experiments 1 and 3 were inconsistent. The greatest difference in concentration of FSH between lines was for 150-d old boars in Experiment 1. But means of the lines at this age in Experiment 3 were similar. The differences in results for the two experiments might be explained by sampling variance. There were fewer observations in the third experiment and, therefore, these means have greater sampling variance.

Workers at MARC found that plasma FSH concentrations were greater in mature Meishan boars than in a composite population of domestic breeds. These breeds differ significantly in ovulation rate. Based on their results, we hypothesized that concentration of plasma FSH in the boar is genetically correlated with ovulation rate.

Our results confirm a positive genetic relationship between ovulation rate of females and plasma FSH concentration of male relatives. The correlation appears to be greatest when plasma FSH of boars is measured between 120 and 150 days of age. The magnitude of this correlation could not be determined precisely from the results of this experiment. Average ovulation rate is approximately 6.5 eggs more for line I than line C gilts; however, ovulation rate was not measured on contemporary gilts to these boars. The differences in ovulation rate, the known selection differential for ovulation rate in the selection experiment, and the range of differences found in concentrations of plasma FSH in this study were used to calculate the possible range of genetic correlation between ovulation rate and concentration of plasma FSH. The range for the correlation was between .25 and .75. If the genetic correlation is .75, selection for plasma FSH concentration in boars to increase ovulation rate will be effective. But if the correlation is .5 or less, this method of selection will not be effective.

Gilts. Line I gilts had greater plasma concentrations of FSH than line C gilts at 50 (P <.01), 90 (P < .01), and

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130 (P < .10) days of age (Table 2). Concentration of FSH declined (P < .01) with age, but line by age interaction was not significant.

Concentration of FSH in plasma is regulated by feedback of ovarian hormones on the hypothalamus, the control center for secretion of gonadotrophin hormones and the anterior pituitary gland which secretes FSH. Other workers have found that there is little ovarian regulation of FSH synthesis in gilts before 50 days of age. Because lines I and C differed at 50 days the mechanism by which selection altered plasma concentration of FSH is probably due to differences in FSH synthesis.

Concentration of FSH in line I gilts was approximately 25 percent greater than in line C gilts. A genetic correlation between ovulation rate and FSH close to 1.0 would have to exist to cause a difference this large. Therefore, plasma FSH concentration in young gilts may be a useful predictor of ovulation rate. It is more easily measured than ovulation rate and, therefore, could be more easily incorporated into a selection program.

[1]Rodger Johnson is Professor of Animal Science and Joe Cassady is a graduate student in the department.

National Swine Improvement Federation Ultrasound Certification Workshops

Doyle Wolverton
Dennis E. Burson
Thomas E. Socha[1]

Summary and Implications

Twenty-three people participated in two National Swine Improvement Federation ultrasound certification workshops in January 1995. Each participant's ability to predict backfat and loin muscle area on live market hogs was determined. IBP Inc,. Madison, Nebraska cooperated in the collection of carcass data for certification purposes. Nine participants were certified for backfat and loin eye readings and eight participants qualified for certification of backfat only. The workshops provided the pork industry with additional expertise in the use of ultrasonic measurements to determine backfat and loin muscle area on live swine.

Introduction

Ultrasonic measurement is a viable method to estimate backfat thickness and loin muscle area in the live pig. However, accuracy of ultrasonic estimates are technician dependent. The National Swine Improvement Federation (NSIF) has implemented programs to standardize ultrasonic measurements for these traits. The first of these programs was held at Iowa State University in the spring of 1994. Two programs were offered at the University of Nebraska in January 1995. The purpose of the workshop was to evaluate the participants ability to predict carcass data, the repeatability of their measurements and the bias of the live measurements as compared to carcass data.

Methods

The two workshops held in Nebraska were jointly sponsored by the Nebraska SPF Swine Accrediting Agency and the University of Nebraska Animal Science Department. Facilities for the workshop were provided by the SENEK Testing station located at Wymore, Nebraska. The pigs used in the practicum were involved in a study conducted by cooperators in the Nebraska SPF program.

The workshops consisted of an educational training session, a scanning practicum for participants, and a written exam. The educational program included the topics of anatomy of the pig, fat and muscle deposition patterns, NSIF recommendations for ultrasound measurements, proper probe placement, discrepancies of live and carcass data, and the use of NSIF adjustment factors. Program presenters included Dr. Dennis E. Burson, Extension Meat Specialist; Dr. Thomas E. Long, Extension Swine Specialist, and Dr. Thomas E. Socha, Manager Nebraska SPF Swine.

Pigs used for measurement by the participants were selected by John McKeever, SENEK Station Manager and Doyle Wolverton, Extension Livestock Specialist. Fifty pigs were scanned in random order by each participant. Participants submitted their first round results before to the second scanning. Pigs were randomized again for a second scanning by the participants. Pigs were shipped directly to IBP Inc., Madison, Nebraska for slaughter the next day. Fat thickness and loin muscle area were collected on the carcasses after a 24-hour chill by carcass officials, Dr. Dennis E.

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Table 1. Carcass information for the two workshops.

Trait	Mean	Standard Deviation	Minimum	Maximum
First Workshop (50 hogs)				
Hot carcass wt, lb	166.6	7.6	154	186
Tenth rib fat, in	1.08	0.24	0.6	1.78
Loin muscle area, sq in	5.45	0.65	4.12	6.65
Second Workshop (50 hogs)				
Hot carcass wt, lb	171.9	7.4	153	193
Tenth rib fat, in	0.90	0.32	0.48	1.98
Loin muscle area, sq in	5.99	1.03	3.55	7.95

Burson and Brian Demos, Graduate Research Assistant.

Certification was granted to technicians who meet specified criteria for prediction of carcass data, repeatability of ultrasound measurements, bias and if they demonstrated proficient knowledge concerning the use of ultrasound and performance data.

The statistics used to evaluate a technician's ability to predict carcass measurements and repeatability of ultrasonic measurements were the standard deviations of prediction, standard deviations of the difference and the bias, which is the average difference between live and carcass measurements. The standards for these statistics were:

Standard deviation of prediction.
- Tenth rib backfat 0.15 in.
- Loin muscle area, tenth rib 0.50 sq. in.

Standard deviation of the difference.
- Tenth rib backfat 0.10 in.
- Loin muscle area, tenth rib 0.40 sq. in.

Bias.
- Tenth rib backfat 0.15 in.
- Loin muscle area, tenth rib 0.05 sq. in.

Results

The carcass information for the pigs used in the two workshops are listed in Table 1. Both workshops were conducted with pigs that were market weight and varied in backfat and loin muscle area.

A total of twenty-three individuals participated in the two workshops. Nine individuals were granted certification for both backfat and loin muscle area and eight individuals were granted certification for backfat only. Six individuals did not meet the certification requirements.

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PigCHAMP Summary of 1994 Reproductive Herd Performance

Mike Brumm
Cate Dewey
Barb Cox
Angela Baysinger[1]

Summary and Implications

A summary of 51 swine herds in the western cornbelt that used PigCHAMP as their reproductive record system during 1994 was completed. This summary documents the wide range in performance that existed among herds. Using 10th and 90th percentiles, farrowing rate ranged from 69.1% to 88.1%, pigs weaned per litter from 8.1 to 9.8, and litters per mated female from 1.76 to 2.36. Overall reproductive performance, reported as pigs weaned per mated female per year, ranged from 14.8 to 22.4 with a 50th percentile value of 19.3. These results can be used for planning and decision making purposes in individual swine enterprises.

Introduction

PigCHAMP is a swine production records software program developed at the University of Minnesota. Although there are many other excellent computer software programs for producer use, PigCHAMP remains one of the most widely used programs by industry advisors.

A challenge for individual producers and their advisors is interpretation of the various reports generated by a record system. The "Performance Monitor" is the most widely used report from PigCHAMP, giving producers and advisors a one-page overview

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of the biological performance of the reproductive herd. While advisors and producers use individual herd performance records to solve problems and set production targets, there is a need for summary information across a number of herds keeping records on the same system.

Advisors, lenders, and others associated with the swine industry are often faced with the challenge of estimating "normal" or "realistic" production for situations such as cash-flow projections and pig-flow projections. In many situations, producers, investors, and advisors are interested not only in the "normal" or average values, but also what a producer can expect if everything goes right, or what a producer can expect if disaster strikes.

Data Collection

Veterinarians in Nebraska, Iowa, Missouri, Kansas, Colorado, and South Dakota who were members of the American Association of Swine Practitioners were contacted in late May, 1995 for the names and addresses of producers using PigCHAMP for sow productivity records. Producers identified in this manner were individually contacted for permission to use data from the 1994 production year. As of September 15, 1995, 61 herds had submitted data files for inclusion in the data set (Table 1).

After conversion to PigCHAMP v3.05, the data from each herd were examined for accuracy and completeness. Herds were excluded from the data summary if:

1) ending female inventory differed from average female inventory by 20% or more
2) farrowing rates were 100% for three consecutive months
3) the weaning to first service interval was less than four days
4) the percent of females mated by seven days postweaning was greater than 96%

Table 1. Geographic distribution of herd data bases evaluated.

State	No. Herds Submitted	No. Herds Included
Colorado	4	3
Iowa	19	17
Kansas	23	19
Missouri	1	0
Nebraska	14	12
Total	61	51

5) preweaning mortality was less than 5%
6) female culling rate was not between 20 and 80%

These culling rate and inventory criteria were established to avoid including herds in the data set that had recently repopulated or herds that were expanding and had a large percentage of gilts in the female inventory.

Results

The 10th and 90th percentile values are reported in Table 2, rather than minimum and maximum values. The 10th and 90th percentiles give an indication of the best or worst values for a production parameter, depending on whether a high or low value is desirable, and minimizes the impact of outlying data points on the values reported. The 50th percentile value represents the median value for the 51 herds in the data set. Twenty-five herds have lower values for the production parameter and 25 herds have higher values.

The average value is the mean for all 51 herds and may differ from the 50th percentile if the data are skewed or if there are a few outlying data points. An example is the wean-to-first-service interval. While the 50th percentile is 7.0 days, the mean of 7.6 days reflects at least one herd that appeared to skip an estrus cycle for all females at weaning when rebreeding (28.6 day interval) and two herds that appeared to skip an estrus cycle for first parity females (14.7 and 12.2 day intervals).

Many producers submitting data did not record gilt entry dates. In many cases, females were not entered into herd inventories until a breeding (service) occurred. Therefore, the data presented in Table 2 are per mated female, not per inventoried female, which is the method used for the Nebraska Swine Enterprise Record results which appear elsewhere in this publication.

Litters per mated female per year was quite variable among the herds in this data set. The average number of litters per mated female was 2.12, with a range of 1.76 to 2.36.

For herds in this data set, females averaged 10.2 pigs born live per litter farrowed in 1994 with 80% of the herds (10th to 90th percentile) reporting 9.4 to 11.1 live born pigs. Pigs weaned per litter was 8.9 with a range

Table 2. Rankings of 1994 reproductive performance from 51 herds using PigCHAMP.

Item[a]	Percentile 10th	50th	90th	Average
Litters weaned, no.	301	822	2013	
Parity of farrowed sows, no.	2.0	3.3	4.1	3.2
Farrowing rate, %	69.1	77.7	88.1	77.3
Pigs born live/litter farrowed, no.	9.4	10.1	11.1	10.2
Preweaning mortality, %	7.6	12.5	17.1	12.2
Pigs weaned/litter farrowed, no.	8.1	8.9	9.8	8.9
Age at weaning, days	18.4	21.2	26.2	21.6
Pigs weaned/mated female/yr, no.	14.8	19.3	22.4	18.9
Litters/mated female/yr, no.	1.76	2.20	2.36	2.12
Wean to first service interval, days	5.1	7.0	9.8	7.6

[a]Each item sorted independently of all other items.

of 8.1 to 9.8 pigs.

The combination of litter size and litters per year is reported as pigs weaned per mated female per year and is often considered the single best measure of reproductive biological efficiency. While the average was 18.9 pigs per mated female, the range was 14.8 to 22.4 pigs (10th to 90th percentile).

These results verify the great variation in biological performance that exists in swine herds in the western cornbelt. Possible causes of this variation include such items as genetic source, facilities, planned production schedules, disease, and management. The use of 10th and 90th percentiles is not meant to imply that producers should strive at all costs to attain the better reproductive efficiency these values represent. Rather, producers are encouraged to consider these values as reasonable performance limits with the understanding that optimal financial efficiency may mean less than maximum reproductive efficiency.

[1]Mike Brumm is a Professor of Animal Science and an Extension Swine Specialist at the Northeast Research and Extension Center, Concord; Cate Dewey was an Assistant Professor Epidemiology, and Barb Cox was a Research Technologist, Veterinary Science at the Great Plains Veterinary Educational Center, Clay Center; Angela Baysinger is an Extension Swine Veterinarian, Department of Veterinary Science at the University of Nebraska, Lincoln.

1995 Nebraska Swine Enterprise Records Program Results

Dale Kabes
Michael Brumm
Larry Bitney[1]

Summary and Implications

Data from cooperators participating in the Nebraska Swine Enterprise Records and Analysis Program were summarized for the period January to June 1995 and July 1, 1994 to June 30, 1995. Results continue to show significant variability in production and financial parameters among individual swine enterprises. The results indicate that efficient, well managed swine enterprises can be profitable and competitive in a dynamic industry.

Average values of several production and financial parameters for farrow-to-finish, and farrow-to-feeder pig enterprises for the first six months of 1995 are given in Tables 1 and 2. Also included in the far right column of each table is annual data from July 1, 1994 through June 30, 1995. In addition to the overall averages for each enterprise type, averages for the high 1/3 profit group and low 1/3 profit group are listed for the farrow-to-

Table 1. Selected items for farrow-to-finish enterprises.

Item	January 1 to June 30, 1995			July 1, 1994 to June 30, 1995
	Average	High 1/3 profit	Low 1/3 profit	
Number of farms	37	12	12	20
Profit/cwt pork produced	$4.75	$11.32	-$2.07	-$1.22
Total cost/cwt pork produced	$40.99	$36.63	$44.20	$39.69
Total variable cost/cwt pork produced	$35.76	$33.24	$38.46	$35.52
Fixed cost/cwt of pork produced	$5.24	$3.39	$5.74	$4.17
Total feed expense/cwt pork produced	$24.27	$23.12	$25.47	$24.05
Average cost of diets/cwt	$6.61	$6.38	$6.79	$6.44
Feed/cwt pork produced, lb	368	362	377	373
Pigs weaned/female/year, no.	17.9	18.3	16.3	17.6
Pigs weaned/crate/year, no.	78.4	81.3	79.2	76.6

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

Item	January 1 to June 30, 1995			July 1, 1994 to June 30, 1995
	Average	High 1/3 profit	Low 1/3 profit	
Number of farms	11	4	4	8
Profit/cwt pork produced	$2.61	$13.38	-$7.55	-$10.24
Total cost/cwt pork produced	$63.16	$60.39	$64.87	$66.56
Total variable cost/cwt pork produced	$53.16	$51.32	$55.44	$54.56
Fixed cost/cwt of pork produced	$10.00	$9.07	$9.43	$12.00
Total feed expense/cwt pork produced	$30.80	$27.05	$34.41	$30.64
Average cost of diets/cwt	$7.91	$7.61	$8.20	$8.34
Feed/cwt pork produced, lb	389	357	419	368
Pigs weaned/female/year, no.	17.2	18.7	15.3	18.2
Pigs weaned/crate/year, no.	89.6	98.5	81	100.3
Average weight of feeder pig sold, lb	50.2	53.9	46.5	49.8

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finish and farrow-to-feeder pig enterprises for the January through June 1995 time period.

The high 1/3 profit producers reported feed costs of $23.12/cwt of pork produced and the low 1/3 profit producers reported feed costs of $25.47/cwt of pork produced, respectively. This resulted in a $2.35/cwt of pork produced advantage for the high profit group. To accomplish this the high profit group had a lower diet cost ($6.38/cwt vs $6.79/cwt of ingredients) and a better feed efficiency (362 vs 377 lb of feed/cwt of pork produced) than the low profit group. Similar increased reproductive efficiencies were reported in pigs weaned per female per year (18.3 vs 16.3 for the high and low profit group, respectively). Corn was valued at $2.37/bu for the first six months of 1995 and $2.24/bu for the 12-month period ending in June 1995.

With constant change in the swine industry, pork producers will have to continually strive to improve their enterprises. Producers will need to identify their strengths and weaknesses and then determine the opportunities and threats for their individual swine enterprise. To accomplish this, producers should begin with an accurate record system and a set of written goals to help lay the path for the future.

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

Slaughter Hog Price Patterns at Omaha

Al Wellman[1]

Summary and Implications

Omaha slaughter hog prices from 1975 to 1994 were used to indicate the price patterns that tend to be repeated year to year. A monthly price index and variability of the monthly price were calculated. Strong seasonal price patterns were observed. The price patterns can be used to determine likely price trends during the year. The price data can be used to assist producers with their marketing plan and price forecasting for the future.

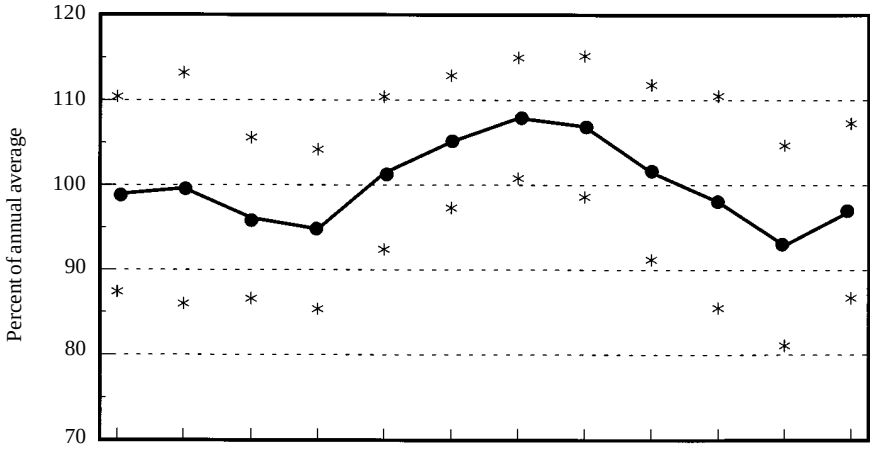
Introduction

Price-risk management strategies require that hog producers have accurate records on past price patterns. The ability to accurately forecast price movements allows the producer to focus on a smaller number of pricing strategies. Knowing the historical patterns of trends, cycles and seasonal price movements can provide a base for forecasting future cash prices. Trends refer to price movements over a period of years. Hog price cycles are fairly regular up and down changes which cover a period of about three to five years. Seasonal price patterns refer to month-to-month or spring-to-summer, summer-to-fall, etc. repeating patterns within a year. This article provides data about seasonal price patterns.

Slaughter hog seasonal price patterns persist from year to year. The price patterns result from changes in hog and pork supplies, changing demand for pork by consumers or a combination of supply and demand changes. Hog prices are affected by the seasonality of farrowings and the resulting supply of pork products. Some seasonal patterns in demand influence hog prices, but the major impact is from supply changes.

Table 1 has the monthly cash prices for Omaha barrows and gilts from 1975 through 1994. By reviewing the past price movements during the year, a determination can be made about the chances that prices will increase or decrease during a particular current or future time period.

Slaughter hog price patterns may change somewhat over time if there are changes in production technology, industry structure or any other factors that offset production patterns or demand. This is reflected by the seasonal price indexes and variability factors in Figure 1. The index primarily reflects the seasonal variation in



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Price index	98.9	99.6	96.1	94.8	101.4	105.1	107.9	106.9	101.5	98.0	92.9	97.0
Variability	11.5	13.6	9.5	9.4	9.0	7.8	7.1	8.3	10.3	12.5	11.8	10.3

Figure 1. Seasonal price index for barrows and gilts at Omaha, 1975 to 1994.

Table 1. Prices ($/cwt) received for barrows and gilts,[1] at Omaha, Nebraska from 1975-1994.[2]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1975	39.78	39.93	40.13	41.03	46.77	43.93	56.67	58.87	61.26	61.10	52.19	50.52	49.35
1976	50.13	49.70	47.34	48.57	49.79	51.86	49.57	44.47	40.14	33.12	33.00	39.17	44.74
1977	40.53	31.06	38.08	37.66	42.62	45.07	46.62	44.81	41.71	41.44	40.55	45.48	41.30
1978	46.70	49.77	48.11	46.88	50.10	49.80	48.03	49.35	50.24	53.15	49.76	51.01	49.41
1979	53.31	55.60	50.67	45.99	45.25	41.82	40.46	38.54	39.52	35.48	36.16	39.66	43.54
1980	38.37	38.63	35.01	29.66	30.28	36.10	43.80	48.54	47.47	48.74	47.25	46.20	40.84
1981	41.38	42.40	39.48	39.60	41.66	47.11	50.47	50.28	49.82	45.89	41.74	39.54	44.11
1982	46.86	50.34	49.86	52.50	58.50	59.63	60.46	63.47	63.36	57.49	54.68	56.71	56.16
1983	57.96	58.69	51.67	48.47	47.96	46.69	47.00	50.02	46.10	42.18	40.16	49.19	48.84
1984	50.88	47.15	47.94	49.13	48.50	51.53	54.63	52.63	47.87	45.50	49.69	51.50	49.75
1985	50.25	49.67	44.68	42.42	43.41	46.93	47.62	44.04	40.68	44.68	45.21	48.07	45.64
1986	46.82	44.44	41.70	41.15	48.62	55.37	61.88	63.76	60.51	55.26	55.04	53.49	52.34
1987	49.31	49.71	48.83	51.91	55.81	60.82	62.20	60.62	55.29	49.20	42.07	42.71	52.37
1988	46.43	48.23	43.20	42.39	48.35	48.89	46.09	46.02	40.85	39.28	37.49	42.91	44.18
1989	43.03	42.12	40.75	38.38	44.36	47.72	48.46	48.17	44.87	48.23	47.15	51.03	45.36
1990	49.33	50.33	53.03	54.80	63.54	61.71	63.18	57.59	55.91	57.83	50.88	49.85	55.67
1991	52.33	52.97	52.52	51.74	55.44	55.75	56.40	51.28	47.18	44.15	38.89	39.45	49.84
1992	37.99	41.32	39.75	42.56	46.65	48.24	45.57	45.43	42.87	43.02	42.49	43.01	43.24
1993	42.39	45.18	47.30	46.25	47.92	49.35	47.07	49.11	48.71	47.78	43.62	41.23	46.33
1994	44.88	48.84	44.70	43.29	43.27	43.78	43.42	42.93	36.15	32.83	29.02	32.90	40.50
20-Year Average													
1974-95	46.43	46.80	45.24	44.72	47.94	49.61	50.98	50.50	48.03	46.32	43.85	45.68	47.17

[1]U.S. No. 1 & 2, 200-220 lbs., 1975-1978; 200-230 lbs., 1979-1984; 210-240 lbs., 1985-88; 230-240 lbs., 1989-1991; 230-250 lbs., 1992-94.
[2]Information compiled from Livestock and Meat Statistics, Livestock Market News, USDA.

price. The variability factor indicates the reliability of the price index for a particular month.

Price Index

A price index of the monthly prices is calculated for the 20-year period. The price index is a measure of the relative level of monthly prices over the calendar year with 100 as the base. The index shows the average relationship of prices in a particular month to the average for all months for the 1975-94 period. The price index of 98.9 for January indicates that in January Omaha slaughter hogs have averaged 98.9 percent of the annual average. In July, the price index is 107.9 indicating prices have risen on the average 9 percent between January and July (107.9 - 98.9).

Price Variability

Variability is a measure of the variation of each month's average price. It is an indication of the reliability of the price index for each month. It is based on the variability of prices for the indicated month during the 1975-94 period.

For example, the January price index value is 98.9 and the variability indicator is 11.5. This means the expected price in January may be as high as 110.4 percent or as low as 87.4 percent of the annual average price in about two-thirds of future years. The smaller the variability factor, the more reliable is the monthly index.

Price Patterns

Price patterns for the 1975-94 period indicate monthly slaughter hog prices were below the yearly average January through April, then increased through July. Prices declined from August to a fall low in November, then improved slightly in December. Priced tended to be above the yearly average from May to September and below the yearly average from January through April and October to December. Lowest prices were in April and November and the highest prices usually were in June, July and August.

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Porcine Reproductive and Respiratory Syndrome (PRRS)

Angela Baysinger[1]

Summary and Implications

The porcine reproductive and respiratory syndrome (PRRS) virus has adverse affects on the breeding herd and growing pigs. Through field experiences and research, the clinical signs, spread, and diagnosis of PRRS are better understood. Vaccination and improved pig flow are tools available to control PRRS but, the ultimate foundation for controlling, eliminating, and avoiding the virus is better management.

Introduction

PRRS was first observed in the United States in 1987 and in Europe in 1990. It has now spread worldwide due to increasing international trade. Trends that may have influenced the spread of PRRS are the move toward high density of pig populations and the increasing size of herds. This article summarizes the current knowledge base and introduces some of the most recent diagnostic, management, and vaccination protocols.

Clinical Signs

The disease is characterized by its effect on the respiratory and reproductive systems. It affects pigs of all ages. Any combination of signs can affect a herd. Some herds test positive serologically but have no clinical disease. Frequently, in a new outbreak the breeding herd is initially affected. Once the disease has gone through the breeding herd, clinical signs are restricted to the nursery and grower/finisher pigs. In other herds the reproductive condition becomes chronic. The clinical signs seen in an acute outbreak of a breeding herd are: abortion, premature farrowing, stillbirths, mummification, conception failure, and lack of appetite. In many herds, the reproductive problems last only three to four months. Affects on suckling piglets are: listlessness, spraddle-leg, and increased preweaning mortality rates.

The most serious effect is usually respiratory disease in young growing pigs after the initial reproductive outbreak. Most pigs recover from PRRS but some die or become chronic poor-doers from secondary infections. PRRS virus tends to persist in infected populations and can give rise to continuing problems in both growing pigs and breeding stock if pig flow or management changes are not instigated. It is hypothesized that inconsistent exposure to PRRS virus following initial infection my not occur among all members of a population. This may lead to pockets of naive animals and subsequently, continuous cycling of the virus in the herd.

Secondary infections due to *Streptococcus suis, Hemophilus parasuis, Salmonella choleraesuis, Bordetella bronchiseptica, Pasteurella multocida type A, hemolytic E. coli, Mycoplasma hyopneumoniae,* and *Actinobacillus pleuropneumonia* become a major problem in nursery and grower/finisher herds. Viruses also isolated have included Swine Influenza virus and Coronavirus. The secondary infections are controlled through management changes, vaccinations and/or antimicrobial therapy. Antibiotic therapy will usually reduce the severity but not eliminate the clinical signs of secondary infections. The changes needed to control the secondary infections are usually farm specific and best recognized through cooperative efforts between the producer and a swine specialist (i.e., veterinarian, extension specialist, or consultant).

Table 1. Risk factors increasing probability of infection by PRRS virus

◆ Large herd size
◆ Housing in one building
◆ Introduction of new animals of unknown health status
◆ Lack of disinfection procedures
◆ Young average parity of herd
◆ Continuous flow of pig movement
◆ High pig density

Epidemiology

PRRS appears to be spread mainly from one herd to another by transfer of infected animals. Airborne spread has been suggested but not confirmed. Spread via semen and artificial insemination has been documented. Semen from recently infected boars may contain virus for up to six weeks. Research results indicate that boars shed virus in semen intermittently. The PRRS virus is inactivated in the environment in the absence of moisture. Its activity is significantly reduced within 6 days if held at 68 °F. The virus **does** persist over time under moist conditions such as deep pits and lagoons. Risk factors analyzed in European outbreaks are summarized in Table 1.

There are no reports of this disease affecting humans or any other animal species, but PRRS virus can infect some bird species. This may only contribute to further infection of swine herds through bird fecal contamination.

Diagnosis of PRRS

The diagnosis of PRRS relies on compiling information from the herd's clinical history, serology (blood testing), pathology (post mortem examinations) and isolation of the PRRS virus from at least one age group of pigs on the farm. There are numerous diagnostic tests now available for PRRS.

Each test has advantages and disadvantages in reference to its ability to diagnose the virus strain and stage of infection.

Serologic profiling is becoming a common practice for detecting exposure to the PRRS virus. Indirect fluorescent antibody (IFA) test has been the primary mean of testing for a herd profile. This test measures the IgG level and it can be used for detection of antibody from seven to 10 days to three to four months post infection. Serum neutralization detects antibodies at nine to 28 days following infection and may persist for up to 365 days. Most recently, an IgM IFA test has been developed. The IgM test detects titers as early as five days post infection but IgM will only be detectable in herds with an acute infection (14 to 28 days post infection). ELISA test has the same sensitivity and specificity as IgG IFA but, it has the ability to identify both the European and American strains of the PRRS virus. These four profiling tests are tools for identifying exposure and potential disease spread within a herd. They are considered a vital step in preparing a herd plan for control and/or eliminations of the PRRS virus. Contact your diagnostic lab to determine what tests are available.

Vaccination Programs

There is currently a modified-live vaccine produced for use against the PRRS virus. This vaccine is not a cure and should only be viewed as a tool in control/elimination plans. The vaccine is labeled for use in nursery pigs (2cc dose IM at weaning). Some individuals are currently advocating the program of a 1cc dose given intra-nasally (IN) to pigs between 2 and 5 days of age and a second 1cc dose given IM at weaning (14 to 28 days of age). This is usually done in conjunction with the vaccinations given to the sow herd. A PRRS vaccination program for sows must be developed and administered through the advice of a veterinarian. All of the legal aspects of this program need to be discussed. Vaccination of adult animals should not be viewed as risk-free due to reports of vaccine-induced abortions.

There have been mixed responses to PRRS vaccination throughout the United States (personal communications). The overall objective of vaccination usage in breeding and growing swine is to reduce the shedding of virus, reduce the secondary infections in growing pigs, and protect naive herds from severe outbreak of PRRS. The most promising use appears to be in stabilizing the breeding herd so that the piglets are not exposed to viral shedding from the sow.

Management Procedures

Management protocols have been established and tested by individuals world wide. The procedures most widely advocated are depopulation/repopulation, partial depopulation, segregated early weaning (SEW), medicated early weaning (MEW), multi-site production, strict all-in/all-out flow, and most recently, North Carolina's McREBEL™ system.

The most provocative aspect of the McREBEL™ system is its practicality. Producers of any size can easily incorporate the protocol into their units' management. The intent of this system is to stop PRRS-associated death losses due to secondary bacterial infections. It is not meant to eliminate the virus but may be a valuable tool in stopping viral circulation.

McREBEL™ PRRS

- ➔ **M**anagement
- ➔ **C**hanges to
- ➔ **R**educe
- ➔ **E**xposure to
- ➔ **B**acteria to
- ➔ **E**liminate
- ➔ **L**osses from PRRS

McREBEL PROCEDURES

- Stop cross fostering of piglets between litters for resizing or saving sick pigs, fall-behinds, and runts.
- Cross-foster piglets to equalize number of piglets per litter only within the first 24 hours of age.
- Only move pigs within farrowing rooms at birth. Do not move sows or piglets between rooms.
- Stop use of nurse sows for weak-born PRRS infected pigs, fall-behinds, and runts.
- Minimize handling of piglets, especially routine antibiotic or extra iron injections.
- Evaluate the effect on clinical disease levels of each nonessential processing or treatment procedure for suckling and nursery pigs.
- Immediately destroy piglets that become very sick and are unlikely to recover completely.
- Hold NO pigs back!! DO NOT move fall-behind or light-weight pigs backward to younger rooms or to nurse sows.
- IMMEDIATELY STOP ALL FEEDBACK of weak born or aborted/stillborn fetuses.
- Nursery pigs should be moved STRICTLY ALL IN-ALL OUT. Leave 2 to 3 days clean-up and disinfectant time between groups.
- Nurseries may be loaded ALL IN by early weaning a few of the oldest, best performing litters from another farrowing room.

These changes must be followed completely to achieve a sudden reversal of PRRS-associated secondary bacterial disease and mortality of suckling and nursery pigs.

Additional Comments

There are many aspects of the PRRS virus that are not completely understood. We are progressing toward control and elimination of the virus but until the development of immunity against PRRS is understood, management improvements are the most beneficial tool to employ. The vaccine seems to be beneficial in specific herd situations but a veterinary/client/patient relationship must be established for off-label protocols. Much more research will evolve before control of the PRRS virus is achievable.

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Pathogenicity of Intestinal Spirochetes Associated with Porcine Colonic Spirochetosis

Gerald E. Duhamel
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Michelle R. Mathiesen[1]

Summary and Implications

We reported on a new species of intestinal spirochete bacterium, Serpulina pilosicoli, associated with a diarrheal disease of grower-finisher swine, called porcine colonic spirochetosis (PCS). In this report we show that Serpulina pilosicoli, associated with outbreaks of PCS in the United States, attached to the cecal surface of chicks while Serpulina innocens, a non-pathogenic intestinal spirochete, did not. These findings support a role for Serpulina pilosicoli as a cause of diarrhea and reduced feed efficiency in swine.

Introduction

Because 80 percent of the total feed cost is associated with the grower-finisher phase of pork production, improved feed efficiency during that period can generate significant cost savings and increase profits. It is known that approximately 76 percent of the basal energy requirement of the pig is derived from absorption of volatile fatty acids (VFA) by the large intestine. In fact, the concentration of VFA produced from microbial fermentation in the lower intestine of swine ranges between 180 and 200 mmoles/L, a range similar to that found in the rumen contents of cattle. In contrast to cattle where most of the VFA absorption takes place in the abomasum, VFA are absorbed from the large intestine of swine. The quantity of VFA absorbed from the pig's lower intestine depends primarily upon the surface area available.

Presently, all weakly β-hemolytic intestinal spirochetes (WBHIS) inhabiting the lower intestine of swine are assigned to the non-pathogenic spirochete species, *Serpulina innocens*. However, certain WBHIS are clearly associated with a non-fatal wasting diarrheal disease of growing swine, called porcine colonic spirochetosis (PCS). We found that the WBHIS associated with PCS are distinct but related to *Serpulina innocens* and we proposed the name *Serpulina pilosicoli* to describe these spirochete bacteria (Table 1). Comparative analyses of *Serpulina pilosicoli* isolated from swine in the United States, Canada, the United Kingdom, and Australia indicated the worldwide distribution of PCS. Because the newly identified *Serpulina pilosicoli* can attach and invade the wall of the lower intestine, we hypothesized that it has the potential to reduce feed efficiency by disrupting VFA absorption. In the present study, we examined several isolates of *Serpulina pilosicoli* for attachment to the surface of chicks' ceca. Attachment of *Serpulina pilosicoli* to the ceca of chicks is indicative of pathogenicity associated with reduced surface area available for absorption of nutrients.

Materials and Methods

Serpulina pilosicoli were obtained from swine with clinical signs or lesions of PCS in Nebraska (n=2), Iowa (n=2), and California (n=3). After confirming the identity of *Serpulina pilosicoli*, using structural, biochemical, and genotypic analyses (Table 1), the spirochetes were compared with *Serpulina innocens* for attachment to the ceca of chicks. One-day-old chicks were inoculated by crop gavage with either sterile medium or medium containing either *Serpulina innocens* or *Serpulina pilosicoli*. On day 7, 14 and 21 post-inoculation, the ceca of control chicks and *Serpulina*-inoculated chicks were collected for bacteriologic and histopathologic examinations.

Table 1. Differentiating features of *Serpulina* spp. isolated from the intestine of swine.

Characteristic	*S. hyodysenteriae*	*S. innocens*	*S. pilosicoli*
Hemolysis	Strong	Weak	Weak
Number of periplasmic flagella	8 to 12	10 to 13	4 to 7
Indole production	Positive	Negative	Negative
Hippurate hydrolysis	Negative	Negative	Positive
16S rDNA PCR†	Negative	Negative	Positive
Associated hosts	Swine Dogs Mice Birds Guinea pigs	Swine Dogs	Swine Dogs Mice Guinea pigs Non-human primates Humans Birds
Associated condition	Swine dysentery	Not pathogenic	Colonic spirochetosis

†PCR = polymerase chain reaction.

Table 2. Attachment of spirochetes to the ceca of chicks challenge-exposed with porcine weakly β-hemolytic intestinal spirochetes.

Isolate	Number of isolates tested	Days post-inoculation†			
		7	14	21	Total
Serpulina pilosicoli	7	13/20	10/13	8/9	31/42
Infection rate (%)		65	77	89	74
Serpulina innocens	1	0/3	0/5	0/6	0/14
Infection rate (%)		0	0	0	0
Sterile medium	Not applicable	0/7	0/3	0/6	0/16

†Number positive for attachment/number challenge-exposed, as determined by histologic examination.

Results

Grossly, the ceca of chicks inoculated with either sterile medium or medium containing either *Serpulina innocens* or *Serpulina pilosicoli* had no notable changes; the cecal contents were yellowish brown, foamy and semisolid. Histologically the ceca of chicks inoculated with sterile medium or medium containing *Serpulina innocens* had tall columnar epithelium without spirochetes. In contrast, the ceca of chicks inoculated *Serpulina pilosicoli* had spirochetes attached along the surface (Table 2). The infection rate of the *Serpulina pilosicoli*-inoculated chicks increased from 65 percent after 7 days, to 77 percent after 14 days and 89 percent after 21 days. No spirochetes were found by culture of ceca from chicks given either sterile medium or medium containing *Serpulina innocens* at any time post-inoculation. In contrast, large numbers of WBHIS were isolated from the ceca of chicks challenge-exposed with *Serpulina pilosicoli*.

Discussion

Detailed phenotypic and genotypic characterization of intestinal spirochetes has lead to major advances in our understanding of the molecular epidemiology of spirochetal diarrhea in humans and animals. Complete agreement was found between structural, biochemical, and genotypic analyses and the results of attachment to the ceca of chicks. On the bases of these results, we concluded that *Serpulina pilosicoli* has the potential to cause reduced surface area for absorption of nutrients from the gut lumen. We found that the infection rates of chicks increased over time, such that it took 21 days to reach 89 percent of the chicks with spirochetes attached to the surface of the ceca.

Porcine colonic spirochetosis is characterized clinically by watery to mucoid diarrhea without blood, or so called "cow-pie scours". Although diarrhea can affect up to 20 percent of swine in the grower-finisher phase of production, depression of weight gain is the most significant finding with PCS and this can result in a significant delay in reaching market weight. Additional animal care is a major problem associated with PCS in all in/all out management systems because of the uneven sizes of the pigs causing disruption of pig flow.

The pathologic changes in chicks inoculated with *Serpulina pilosicoli* were similar to those present in the early stages of colonic spirochetosis in humans, swine and other animals. In swine, the large intestine contains abundant watery-green or yellow mucoid materials and variable degree of exudation and surface erosions are sometimes visible. Early in the infection spirochetes attach by one of their ends along the surface of the lower intestine producing what appears as a dark fringe when examined histologically. The loss of surface area in the large intestine of pigs accounts for the reduced feed efficiency and increased numbers of days to market. Over longer periods of time, infection with *Serpulina pilosicoli* causes inflammation of the wall of the lower intestine, a lesion referred to as "non-specific colitis". Based on the changes observed in the ceca of the chicks, this change must take longer than 21 days to develop.

Because of the diversity of WBHIS normally present in the intestinal tract of swine and the widespread occurrence of non-pathogenic WBHIS, isolation of WBHIS from swine is only suggestive of PCS. Demonstration of spirochetal attachment to the surface of the lower intestine confirms the diagnosis of PCS; however, necropsy of pigs is not routinely performed in uncomplicated cases of PCS. Assessment of several laboratory procedures for rapid and accurate identification of *Serpulina pilosicoli* indicates that a preliminary identification of the spirochete can be made on the basis of positive hydrolysis of hippurate. Definitive identification of *Serpulina pilosicoli* requires amplification of a specific 16S rDNA gene sequence by polymerase chain reaction. Why is it then that *Serpulina pilosicoli* is only reported sporadically as a cause of diarrhea and colitis in swine? This may be attributable to either *(1)* failure to use appropriate techniques for primary isolation of the spirochete from intestinal specimens, *(2)* failure to identify the spirochete from diagnostic specimens, or *(3)* failure to identify lesions of PCS in tissues submitted for diagnostic evaluation. *Serpulina pilosicoli* also has been isolated from stool samples obtained from children with diarrhea in developing countries and from immunocompromized adult individuals infected with the human immunodeficiency virus in more developed countries. Because *Serpulina pilosicoli* are isolated from humans and swine affected with PCS, it raises the possibility that these spirochetes may be zoonotic and have a public health significance.

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Bioavailability of Iron in Two Different Sources for Weanling Pigs

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Summary and Implications

The bioavailability of the iron in iron methionine was compared with that in feed-grade ferrous sulfate. Pigs, which were anemic at weaning, were given diets containing supplements of one of the two iron sources. Iron supplementation increased weight gain and hemoglobin repletion. The increases were greater for ferrous sulfate than for iron methionine. This indicates that the iron in ferrous sulfate is more bioavailable than the iron in the iron methionine source that we investigated.

Introduction

Iron is an essential trace mineral required by swine during all stages of life. Iron needs are particularly high during rapid growth periods. The most critical period is between birth and weaning because of the rapid growth occurring and because of the very low iron content of sows' milk. Most pigs are given an iron injection within the first few days after birth that will usually satisfy their iron needs until weaning. After weaning, iron nutrition is also critical because of the continued rapid growth and the poor feed intake that often occurs during early postweaning.

Several different iron sources can be used in the trace mineral premix for weanling pigs. They can be broadly divided into inorganic sources, such as ferrous sulfate ($FeSO_4 \cdot H_2O$), and organic sources, such as those offered by several commercial manufacturers. Organic sources are generally more expensive than inorganic sources per unit of total iron, but they may confer advantages not offered by the inorganic sources. One potential advantage is higher iron availability to the animal (bioavailability). Higher bioavailability could mean that less supplemental iron from organic sources is needed, and this could partially offset the higher cost.

We have begun a series of experiments to evaluate different organic iron sources and to compare them to a standard inorganic source. We chose as our standard source feed-grade ferrous sulfate ($FeSO_4 \cdot H_2O$), a common source of iron added to swine diets. Two experiments are described in this report. In the first, we established the linear response range of weight gain and blood hemoglobin concentration to ferrous sulfate. In the second, we compared ferrous sulfate and a commercial organic source of iron—iron methionine.

Methods

In each experiment, pigs were given no supplemental iron (either oral or injectable) from birth until weaning. At weaning (approximately 21 days), pigs were bled and their hemoglobin concentrations were measured. Based on their hemoglobin concentration, 72 barrows and 72 gilts were selected for each experiment. The average initial weights and initial hemoglobin concentrations were 9.8 and 10.9 lb and 4.4 and 4.5 g/100 mL in Experiments 1 and 2, respectively. The normal hemoglobin concentration is 8 to 12 g/100 mL.

In the first experiment, pigs were allotted to a basal diet (Table 1) containing 54 mg/kg (or ppm) of iron or to diets containing 12.5, 25, 50, 100, or 200 mg/kg of supplemental iron from feed-grade ferrous sulfate. The basal diet was designed to be deficient in iron, and the purpose of the experiment was to ensure that iron was the limiting nutrient and that performance and hemoglobin concentrations would be increased when supplemental iron was added. There were 36 pens (six per treatment) with two barrows and two gilts per pen. Pigs were allowed continuous access to feed and water, and the experiment lasted three weeks.

Table 1. Composition and nutrient analysis of the basal diet (as-fed basis)[a]

Item	Amount
Ingredient, %	
Corn	51.98
Soybean meal (46.5% CP)	5.00
Dried skim milk	30.00
Spray-dried porcine plasma	6.00
Corn oil	4.00
Monosodium phosphate	1.00
Limestone	.75
Salt and trace minerals[b]	.27
Vitamin premix[c]	1.00
Analyzed nutrient content	
Crude protein, %	20.6
Lysine, %	1.43
Calcium, %	.80
Phosphorus, %	.79
Iron, mg/kg	54
Copper, mg/kg	12
Zinc, mg/kg	115

[a]Composition of the basal diet. The other five diets contained additions of 12.5, 25, 50, 100, and 200 mg/kg iron from $FeSO_4 \cdot H_2O$.
[b]Supplied 2.5 g of NaCl per kilogram of complete diet and the following amounts of trace elements in milligrams per kilogram of complete diet: Cu (as $CuSO_4 \cdot 5H_2O$), 10; I (as $Ca(IO_3)_2$), .2; Mn (as MnO), 20; Se (as Na_2SeO_3), .3; and Zn (as ZnO), 100.
[c]Supplied the following amounts of vitamins per kilogram of complete diet: retinyl acetate, 4,400 IU, cholecalciferol, 550 IU; *all-rac*-α-tocopheryl acetate, 22 IU; menadione (as menadione sodium bisulfite complex), 3.3 mg; riboflavin, 5.5 mg; niacin, 33 mg; *d*-pantothenic acid (as *d*-calcium pantothenate), 22 mg; cyanocobalamin, 22µg; and choline (as choline chloride), 110 mg.

The purpose of the second experiment was to compare the bioavailability of iron in iron methionine with that in ferrous sulfate. Iron methionine is a commercial source of organic iron in which the iron molecule is complexed with the amino acid methionine. Pigs were allotted to the same basal diet or to diets containing 75 or 150 mg/kg

iron from ferrous sulfate or 50, 100, or 150 mg/kg iron from iron methionine. Other features of the second experiment were similar to those of the first.

Results and Discussion

The results of the first experiment are in Table 2. Average daily feed intake, average daily gain, and feed efficiency all increased linearly as supplemental iron increased from 0 to 200 mg/kg. The results for average daily gain are illustrated in Figure 1. Pigs fed the basal diet without supplemental iron performed very poorly and became progressively more anemic as the experiment progressed. Some pens of pigs lost weight during the experiment and could not be included in the summary of results. Pigs fed diets with 12.5 or 25 mg/kg of supplemental iron were also unable to increase their hemoglobin concentration as the experiment progressed. However, pigs fed diets with the three highest levels of supplemental iron increased in hemoglobin concentration from the beginning to the end of the experiment. As a result, at the end of the experiment there was an increase in hemoglobin concentration as supplemental iron concentration increased. Thus, the results of the first experiment demonstrated that the basal diet was indeed limiting in iron and that performance could be improved by iron supplementation. Based on these findings, we decided to use the same basal diet with supplements of iron up to 150 mg/kg in the second experiment.

In the second experiment, weight gain increased in response to supplemental iron intake from both ferrous sulfate and iron methionine. However, the increases were greater for ferrous sulfate than for iron methionine supplementation. As shown in Figure 2, the ratio between the slopes of the two response lines was 81.4%. This indicates that, based on weight gain, the iron in iron methionine was approximately 81% as bioavailable as the iron in ferrous sulfate. Similar findings were observed when blood hemoglobin con-

Table 2. Effects of iron supplementation on growth and blood hemoglobin of weanling pigs[a]

	Supplemental Fe, mg/kg[b]						
Item[c]	0[d]	12.5	25.0	50.0	100.0	200.0	P-value[e]
ADFI (0 to 3 wk), lb	.311	.331	.417	.439	.551	.710	L<.01
ADG (0 to 3 wk), lb	.075	.097	.187	.212	.344	.494	L<.01
Gain/Feed (0 to 3 wk)[f]	.282	.323	.427	.485	.621	.695	L<.01 Q<.07
Hemoglobin (wk 0), g/dL	4.28	4.57	4.35	4.63	4.41	4.40	NS
Hemoglobin (wk 1), g/dL	4.21	4.13	4.15	4.67	4.72	5.22	L<.01
Hemoglobin (wk 2), g/dL	4.11	4.24	3.88	4.73	5.31	6.40	L<.01
Hemoglobin (wk 3), g/dL	3.85	4.29	4.23	5.18	6.61	8.34	L<.01

[a]Data represent least squares means of six pens per treatment (each pen contained two barrows and two gilts). Three-week experiment. Average initial weight 9.8 lb; average final weight 14.9 lb.
[b]Supplemental Fe was provided as $FeSO_4 \cdot H_2O$.
[c]ADFI = average daily feed intake, ADG = average daily weight gain, and Gain/Feed = feed efficiency.
[d]One pen removed after 2 wk because of considerable weight loss.
[e]L = linear effect, Q = quadratic effect, and NS = nonsignificant effect.
[f]Does not include data from three pens (two with 0 added iron and one with 12.5 mg/kg added iron) that lost weight.

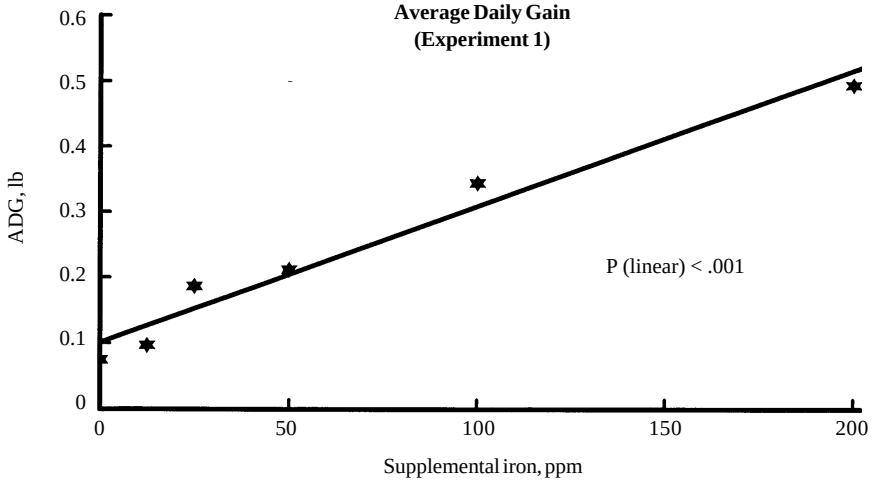

Figure 1. The effect of supplemental iron intake from feed-grade ferrous sulfate on weight gain of weanling pigs.

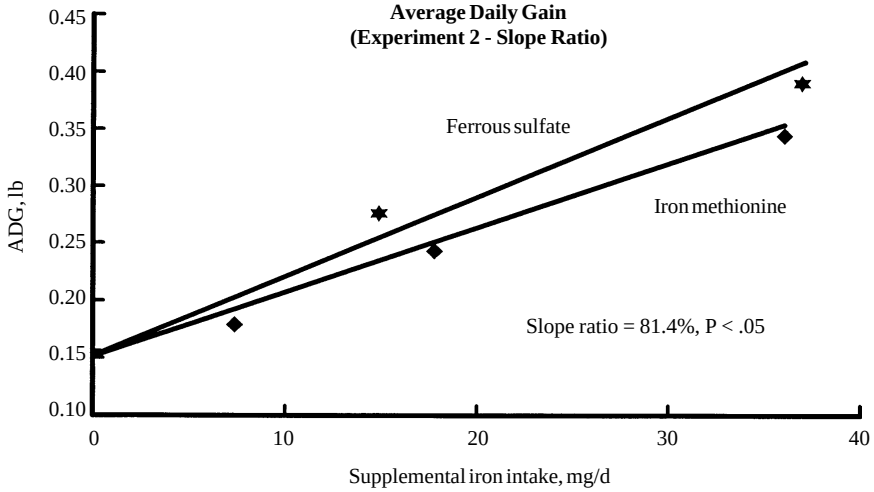

Figure 2. Slope ratio comparison of the effect of ferrous sulfate and iron methionine on weight gain of weanling pigs.

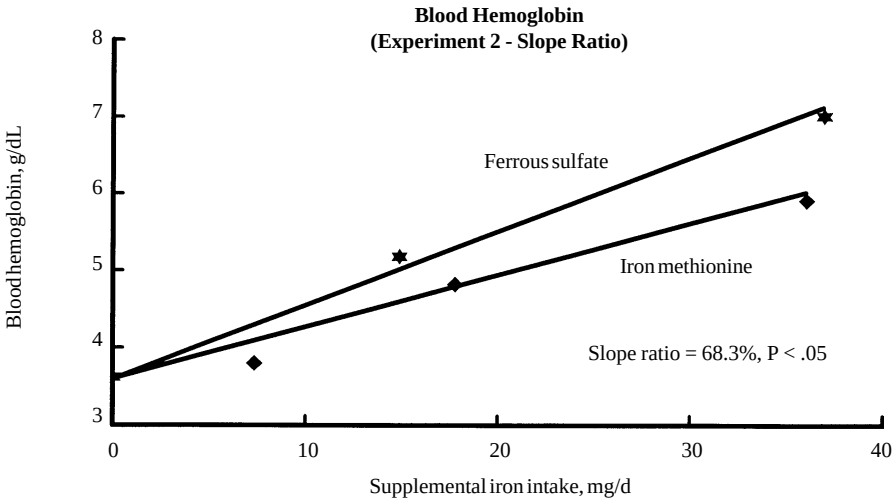

Figure 3. Slope ratio comparison of the effect of ferrous sulfate and iron methionine on blood hemoglobin concentration of weanling pigs.

centrations were measured (Figure 3). Based on hemoglobin concentration, the iron in iron methionine was 68% as bioavailable as the iron in ferrous sulfate.

Thus, using procedures described in these studies (hemoglobin repletion assays) we conclude that the iron in iron methionine is less bioavailable than the iron in ferrous sulfate. The reason for the difference between bioavailability estimates based on weight gain and hemoglobin are unknown, but similar findings have been reported in previous research.

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

New Swine Nutrition Guide Available

Duane E. Reese[1]

Summary and Implications

A new swine nutrition guide from the University of Nebraska and South Dakota State University is available for pork producers, veterinarians, and others. The guide addresses many fundamentals of swine nutrition and modern feeding program design. Single copies are available for $1 from a Cooperative Extension Office in Nebraska or by writing to Swine Nutrition, PO Box 830918, Lincoln, NE 68583-0918. Mail orders must include 55 cents shipping and appropriate sales tax. The guide should help readers develop better feeding strategies for pigs.

Pork production is rapidly becoming a sophisticated, low-margin business. It is necessary that producers, veterinarians and others better understand certain principles of swine nutrition so that better feeding programs for individual swine enterprises can be developed. Therefore, seven swine nutritionists from the University of Nebraska and South Dakota State University recently published a new nutrition guide. It replaces Swine Diet Suggestions. The new publication includes items such as:

- updated nutrient recommendations for all the traditional classes of swine, plus breeding boars and 2-week-old weaned pigs;
- amino acid recommendations for high, medium, and low lean gain growing-finishing pigs and for lactating sows producing heavy and light litters;
- amino acid, calcium, and phosphorus recommendations given as percent of the diet and amount/day and when it is appropriate to adjust nutrient density according to feed intake;
- acceptable ranges for vitamin and trace mineral recommendations to allow feed manufacturers greater flexibility in preparing custom products;
- digestible lysine and available phosphorus recommendations for many common feedstuffs to allow diets containing nontraditional feedstuffs to be formulated more precisely;
- a review of the effect of many feed additives on pig performance;
- a comprehensive list of mineral and vitamin sources, which highlights the ones that are most frequently used, and the relative bioavailability of nutrients from each source;
- relative feeding value of several energy and amino acid (protein) sources;
- how to use the fat-free lean index from packer kill sheets to design diets for growing-finishing pigs;

- a discussion of the various methods of supplying nutrients to pigs (i.e., complete feed, concentrate or supplement, basemix, or premix) and how to make a choice;
- factors affecting feed intake of pigs; and
- advice about high levels of zinc in starting pig diets, betaine, phase feeding, separate sex feeding, proteinated trace minerals, low protein corn, low test weight grains, feed processing, and more.

In Nebraska, the new publication is available at a Cooperative Extension Office for $1. It also can be ordered by writing to Swine Nutrition, PO Box 830918, Lincoln, NE 68583-0918. Nebraska residents may order single copies at the above address for $1, plus appropriate sales tax, plus 55 cents shipping. Non-residents of Nebraska may order single copies from the above address for $1 plus 55 cents shipping. Payment must be included with the order. Orders over $10 will be invoiced with appropriate shipping and handling charges.

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The Effects of Dietary Protein Concentration on Performance and Visceral Organ Mass in Finishing Barrows and Gilts

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

Summary and Implications

The response of finishing barrows and gilts to five dietary protein concentrations was evaluated. Barrows and gilts have different requirements for protein and differ in their sensitivities to excessive intakes of protein. Gilts appeared to be affected by dietary protein concentrations to a greater extent than did barrows. Significant differences in weight gain did not occur but, the lowest average daily gain was for pigs fed the two highest protein levels. Increased dietary protein concentration resulted in increased liver, kidney, and pancreas weights. These data indirectly suggest that maintenance energy requirements of barrows and gilts may be increased as dietary protein concentration is increased, even though there was no significant reduction in growth rate or feed efficiency. Consumption of protein above the requirement (corn-soybean meal diets) results in protein (amino acids) wastage because the animal is unable to convert dietary amino acids to body protein.

Introduction

In the 1994 Nebraska Swine Report, we described an experiment where we found that feeding high-protein diets to growing-finishing gilts reduced growth performance and carcass protein accretion but increased carcass leanness. Because the response of pigs to dietary protein concentration varies with the genetic and physiological characteristics of the pig, we hypothesized that barrows and gilts might respond differently to protein intake. Therefore, the present experiment was conducted to evaluate the effect of dietary protein concentration on growth performance in barrows and gilts and to identify potential physiological mechanisms responsible for the reduced performance of barrows and gilts that consume excessive protein.

Procedures

Sixty crossbred pigs (30 barrows and 30 gilts) with an initial body weight of 112 lb were allotted to a randomized complete block experiment with a 2 x 5 factorial arrangement of treatments. There were two sexes (barrow and gilt) and five protein levels (13, 16, 19, 22, and 25% crude protein [CP]). Diets (Table 1) were corn-soybean meal-based and were fortified with vitamins and minerals to meet or exceed the National Research Council requirements for 110- to 240-lb pigs. The range of CP levels was obtained by changing the ratio of corn to soybean meal.

Pigs were housed individually in an environmentally regulated facility and had *ad libitum* access to feed and water throughout the experiment. Pigs were weighed and feed intakes were measured weekly to determine aver-

(Continued on next page)

Table 1. Composition of diets[a]

Item	Dietary protein concentration, %				
	13	16	19	22	25
Ingredient, %					
Corn	85.15	77.40	69.75	61.85	54.10
Soybean meal, 46.5% CP	12.35	20.25	28.00	36.00	43.90
Dicalcium phosphate	1.00	.80	.65	.50	.35
Limestone	.40	.45	.50	.55	.55
Salt	.30	.30	.30	.30	.30
Trace mineral premix	.10	.10	.10	.10	.10
Vitamin premix	.70	.70	.70	.70	.70
Nutrient composition[b]					
Crude protein, %	11.98	15.23	17.63	20.95	24.14
Lysine, %	.56	.79	1.00	1.12	1.32
Calcium, %	.53	.57	.54	.56	.52
Phosphorus, %	.48	.49	.47	.48	.49
Metabolizable energy, kcal/lb[c]	1,501	1,496	1,491	1,485	1,480

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

Table 2. Effect of protein level and sex on growth performance

Sex		Barrow					Gilt				
Item[a]	CP, %	13	16	19	22	25	13	16	19	22	25
No. of pigs		6	6	6	6	6	6	6	6	6	6
Day 0 to 35											
ADG, lb[b]		2.12	2.09	2.33	2.10	2.14	2.03	2.13	1.92	1.93	1.85
ADFI, lb[d]		7.45	7.21	7.28	7.07	7.00	7.35	7.40	6.76	6.80	6.44
Feed/gain[b]		3.55	3.46	3.12	3.37	3.28	3.64	3.49	3.55	3.55	3.49
Day 35 to slaughter											
ADG, lb		1.82	1.88	1.90	1.72	1.77	1.88	1.96	1.79	1.69	1.76
ADFI, lb[c]		7.00	7.50	7.18	7.07	7.04	6.68	7.13	6.62	5.98	6.15
Feed/gain[b]		3.83	3.96	3.79	4.12	4.04	3.61	3.64	3.71	3.57	3.49
Day 0 to slaughter											
ADG, lb		1.96	1.98	2.10	1.90	1.94	1.95	2.04	1.85	1.80	1.80
ADFI, lb[ce]		7.21	7.36	7.22	7.07	7.02	6.99	7.26	6.69	6.36	6.29
Feed/gain		3.69	3.72	3.44	3.73	3.64	3.62	3.56	3.63	3.55	3.49

[a]ADG = average daily gain and ADFI = average daily feed intake.
[b]Main effect of sex (P<.01).
[c]Main effect of sex (P<.05).
[d]Linear effect of protein (P<.01).
[e]Linear effect of protein (P<.05).

age daily gain (ADG), average feed intake (ADFI), and the ratio of feed: gain (ADFI/ADG).

Pigs remained on the experiment until the average body weight reached approximately 250 lb. Three blocks of pigs were randomly selected and slaughtered after a 24-hour fast. Organs were separated and weighed immediately after slaughter. Weights of the following organs and tissues were obtained: 1) liver with gall bladder removed; 2) heart with blood clots removed; 3) kidneys; 4) leaf fat; 5) pancreas with associated fat tissue removed; 6) stomach, which was weighed full and after contents were removed; and 7) intestinal tract, which was weighed full and after contents were removed. Intestine was separated into small and large intestines and mesentery.

Results and Discussion

Growth Performance. Average daily gain, average daily feed intake, and feed/gain data are presented in Table 2. The experimental period was divided into two periods to examine the response pattern associated with diet and sex. Barrows grew faster and utilized feed more efficiently (P<.01) than gilts in the first period (day 0 to 35). In the second period (day 35 to 75), barrows ate more feed (P<.05) but utilized feed less efficiently (P<.01) than gilts. Overall, ADG and ADFI/ADG were not influenced by either sex or dietary protein concentration. However, increasing protein level decreased ADFI (P<.05) and the reduction was greater in gilts than in barrows (P<.05). The results of growth performance from this experiment were different from our observations in the 1994 Nebraska Swine Report, where high protein levels reduced ADG. Although differences in weight gain in the present study were not statistically significant, the lowest ADG was for pigs fed the two highest protein levels. The differences between the two experiments may be due to the genetic background and weight range of pigs and the inclusion of barrows in the present experiment.

Organ weights. Data for organ weights are summarized in Table 3. Barrows had lighter kidney and stomach weights (P<.01) than gilts. Increased protein level resulted in increased liver, kidney (linear, P<.01), and pancreas weights (linear, P<.05), whereas weight of mesentery tissue (primarily fat) was decreased as protein level increased (linear, P<.05). The liver and kidney are the major sites of amino acid degradation and nitrogen clearance. Increased weight of liver and kidney found in this experiment may be related to the higher amounts of nitrogenous compounds processed by these organs. The weight of pancreas was also increased with increasing dietary protein. The result

Table 3. Effect of protein level and sex on organ weight[a]

	Sex	Barrow					Gilt				
Item	CP, %	13	16	19	22	25	13	16	19	22	25
Liver, g[c]		1340	1385	1441	1704	1655	1395	1500	1649	1588	1816
Heart, g		419	351	444	400	387	371	354	400	373	399
Kidney, g[bc]		336	288	328	381	382	315	372	417	402	442
Spleen, g		193	157	192	156	165	188	152	172	173	167
Pancreas, g[d]		114	134	138	134	126	111	132	140	139	166
Stomach, g[b]		554	545	535	539	529	573	672	567	563	579
Small intestine, g		1421	1300	1361	1453	1540	1237	1425	1363	1562	1437
Large intestine, g		1036	1156	987	1063	1142	975	1165	1068	1026	1045
Leaf fat, g		2629	2023	1821	2328	2106	2557	1693	2295	2094	2011
Mesentery tissue, g[c]		1893	1859	1522	1882	1432	1785	1835	1893	1549	1583

[a]Final empty-body weight was used as a covariate in the statistical analysis. Empty-body weight = (live weight minus gastrointestinal contents).
[b]Main effect of sex (P<.01).
[c]Linear effect of protein (P<.01).
[d]Linear effect of protein (P<.05).

reflected that greater amounts of pancreatic enzymes were required to digest the larger quantity of protein consumed by pigs fed the high protein diets. These data indirectly suggest that maintenance energy requirements of barrows and gilts may be increased as dietary protein concentration is increased, even though there was no significant reduction in growth rate or feed efficiency.

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

Performance of Growing-Finishing Pigs Consuming Diets Formulated on an Ideal Protein (First Four Limiting Amino Acids) Basis

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

Summary and Implications

An experiment with growing-finishing pigs was conducted to evaluate the effects of a corn-soybean meal diet supplemented with crystalline amino acids in an ideal pattern for the first four limiting amino acids (lysine, tryptophan, threonine, and methionine) on growth performance, plasma urea concentration, and carcass characteristics in barrows and gilts. Barrows were pair-fed to gilts within the same dietary treatment. For the entire growing-finishing period, there was a diet x sex interaction for daily gain and feed efficiency. Barrows and gilts consuming a corn-soybean meal diet performed similarly; however, barrows receiving diets formulated on an ideal protein basis had a 10 percent lower daily gain and a four percent lower daily feed intake than gilts. Barrows and gilts receiving the ideal protein diet gained weight more slowly and consumed less feed during the growing-finishing period than did pigs receiving the intact corn-soybean diet. Diet did not affect the percent lean in the carcass. Plasma urea concentrations showed that nitrogen was conserved in pigs consuming the ideal protein vs intact corn-soybean meal diet. Differences in plasma urea concentration were not observed between barrows and gilts within either treatment. These results indicate there is no advantage in terms of daily gain and feed efficiency of providing growing-finishing pigs an ideal protein diet. However, feeding an ideal protein diet will reduce the amount of nitrogen the pig wastes. Future research will focus on the effects of ideal protein diets on nitrogen excretion and amino acid utilization.

Introduction

The concept of ideal protein is currently being reviewed by swine nutritionists. An ideal protein is one that supplies essential amino acids and nonessential nitrogen in the exact proportions to meet the requirements for maintenance and growth. Therefore, no amino acid deficiencies or excesses exist with ideal protein diets. Because grain-soybean meal diets do not have an ideal amino acid pattern, excess protein must be provided to meet the amino acid requirement for the first limiting amino acid (e.g., lysine). Consequently, many other amino acids are consumed in excess of the requirement for growth and must be broken down and converted to energy or fat. This breakdown of amino acids results in the production of urea and the excretion of nitrogen (urea; (NH_2-CO-NH_2)).

One strategy is to use the ideal protein concept to reduce the amount of nitrogen excreted by growing-finishing pigs consuming grain-soybean meal diets. However, it is important to recognize that growth performance may also be affected.

The primary objective of this experiment was to examine the effects on growth response, carcass characteris-

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tics, and plasma urea concentration of growing-finishing pigs fed corn-soybean-meal-amino acid supplemented diets formulated on an ideal protein basis for the first four limiting amino acids. Secondly, we attempted to compare the responses of barrows and gilts by pair-feeding the barrows to the feed intake of the gilts.

Procedures

Thirty-six crossbred pigs (18 gilts and 18 barrows) with an initial weight of 58.6 lb were used in an experiment with a randomized-complete block arrangement of treatments and animals. All pigs were individually penned in one environmentally controlled room kept at 72°F. Pigs remained on the study for 98 days. Pigs were weighed, feed disappearance was determined, and blood samples were taken weekly. Plasma samples were subsequently analyzed for urea. At the end of the experiment, pigs were shipped to a packer in northwestern Iowa. Carcass characteristics were acquired from relationships derived using Total Body Electrical Conductivity (TOBEC). These included ham weight, loin weight, shoulder weight, and carcass lean percentage (5% fat basis).

The dietary treatments used in the experiment are presented in Table 1. Phase 1 diets were offered until pig weight was approximately 113 lb (4 weeks). Phase 2 diets were provided from 113 to approximately 237 lb. Within each phase, corn-soybean meal (INTACT) or corn-soybean meal-amino acid supplemented (IDEAL) diets were fed. Nine gilts and nine barrows received one of the aforementioned dietary treatments. One gilt allotted to the INTACT diet died and was not included in the statistical analysis. In addition, carcass weights and characteristics of three barrows receiving the IDEAL diets were not included in the statistical analysis. In the IDEAL diets, the protein concentration was reduced approximately four percent from the INTACT diet (19.1 to 14.6%, Phase 1; 16.2 to 12%, Phase 2). Crystalline amino acids (lysine, threonine, methionine, and tryptophan) were added to the IDEAL diet to meet the lysine concentration of the INTACT diet and provide an amino acid pattern (relative to lysine) similar to the ideal pattern developed at the University of Illinois. The lysine percentages between the INTACT and IDEAL diets presented in Table 1 differ slightly to allow for differences in amino acid digestibility. The concentration of lysine and the ratios used for the next three limiting amino acids were based on calculated apparent ileal digestible values (Table 2).

Gilts had *ad libitum* access to the respective Phase 1 and 2 diets and to water during the entire experiment. Barrows were pair-fed according to the mean feed intake of the respective gilt treatment group (three- or four-day average). Average feed intake of the gilt groups was expressed per unit of body weight. This factor was multiplied by individual barrow weight to determine the daily feed allowance for each barrow.

Table 1. Diet composition (%) and calculated chemical analysis (as-fed basis).

Item	Phase 1[a]		Phase 2[a]	
Diet,	INTACT[b]	IDEAL[b]	INTACT	IDEAL
Corn	66.60	78.25	74.40	85.30
Soybean meal, 46.5% CP	28.90	16.35	21.20	9.50
Tallow	2.00	2.00	2.00	2.00
Dicalcium phosphate	.95	1.20	.90	1.10
Limestone	.45	.40	.40	.35
Salt	.30	.30	.30	.30
Vitamin mix	.70	.70	.70	.70
Trace mineral mix	.10	.10	.10	.10
L-lysine•HCl	—	.39	—	.36
L-threonine	—	.15	—	.13
DL-methionine	—	.10	—	.08
L-tryptophan	—	.04	—	.05
Calculated composition				
Crude protein, %	19.1	14.6	16.2	12.0
Lysine, %	1.00	.97	.80	.77
Calcium, %	.65	.66	.60	.60
Phosphorus, %	.55	.55	.55	.55
Metabolizable energy, Mcal/lb	1.53	1.52	1.54	1.53

[a]Phase 1 = 58.6 to 113 lb; phase 2 = 113 to 237 lb.
[b]INTACT = corn-soybean meal diet; IDEAL = corn-soybean meal-amino acid supplemented diet.

Table 2. Total and apparent ileal digestible amino acid compositions of diets (as-fed basis).

Item	Phase 1[a]		Phase 2[a]	
Diet,	INTACT[b]	IDEAL[b]	INTACT	IDEAL
Lysine, %	1.00(.84)[c]	.97(.84)	.80(.66)	.77(.66)
Tryptophan, %	.24(.18)	.22(.16)	.20(.14)	.19(.13)
Threonine, %	.73(.56)	.71(.56)	.63(.47)	.60(.46)
Methionine + cysteine, %	.61(.53)	.61(.53)	.55(.47)	.53(.46)
Isoleucine, %	.81(.68)	.60(.50)	.68(.57)	.49(.40)
Valine, %	.90(.79)	.71(.60)	.78(.68)	.60(.50)

[a]Phase 1 = 58.6 to 113 lb; phase 2 = 113 to 237 lb.
[b]INTACT = corn-soybean meal diet; IDEAL = corn-soybean meal-amino acid supplemented diet.
[c]Values in parentheses represent calculated apparent ileal digestible percentages.

Results and Discussion

The performance of barrows and gilts consuming the INTACT and IDEAL diets for Phase 1, Phase 2, and the overall growing-finishing period is presented in Table 3. Although barrows were heavier at the start of the experiment, initial weight was not used as a covariate.

During Phase 1, gilts consumed

more feed (P < .05) and gained more weight (P < .05) than barrows. Barrows fed the IDEAL diet during Phase 1 had a 14 percent lower average daily gain (ADG) compared to gilts consuming the same diet; however, barrows and gilts fed the INTACT diet gained similarly (diet x sex, P < .05). Compared to gilts, feed efficiency was reduced in barrows consuming the IDEAL diet but not the INTACT diet (diet x sex, P < .05).

Barrows and gilts receiving the IDEAL diet consumed less feed (P < .05) and had lower ADG (P < .05) than barrows and gilts consuming the INTACT diet during Phase 2. Likewise, averaged for the entire experimental period, pigs consuming the INTACT diet gained weight 10 percent faster (P < .05) and consumed six percent more feed than pigs in the IDEAL group. The diet x sex interaction (P < .05) for ADG and feed efficiency was a result of the reduced ADG observed for barrows consuming the IDEAL diet.

Performance criteria suggest that the pair-feeding of barrows to gilts resulted in similar feed intakes for barrows and gilts consuming the INTACT diets. However, for the entire growing-finishing period, barrows had a 10 percent lower ADG and a four percent lower average daily feed intake (ADFI) than gilts receiving the IDEAL diet. Therefore, for the entire experimental period, gilts seemed to utilize the IDEAL diet more efficiently than barrows.

The reduction in feed efficiency and(or) the efficiency of amino acid utilization in barrows vs gilts consuming the IDEAL diets not only reduced ADG, but also reduced the pair-feeding allotment (barrows feed allotment was calculated according to body weight). This observation in part could be a result of barrows receiving their feed allotment once daily rather than in two to three allotments during a 24-hour period. The efficiency of lysine utilization from amino-acid supplemented diets can be reduced if the feed is consumed over a short time period. However, this is not supported by the response of plasma urea concentrations observed in this study (Figure 1). Barrows and gilts consuming the IDEAL diets had reduced plasma urea concentrations compared to barrows and gilts receiving the INTACT diets. Within both the INTACT and IDEAL treatments, plasma urea was similar for barrows and gilts. These latter observations are consistent with reduced crude protein (nitrogen) content of the IDEAL diets.

Carcass characteristics are presented in Table 4. The diet x sex inter-

(Continued on next page)

Table 3. Performance criteria of barrows and gilts consuming intact corn-soybean meal and ideal protein diets.

Item[a]	Diet, Sex,	INTACT[b]		IDEAL[b]		SEM[c]
		Gilts	Barrows	Gilts	Barrows	
No. of pigs		8	9	9	9	
Phase 1						
Initial wt., lb[e]		57.4	59.4	58.0	59.4	.80
Final wt., lb[f]		112.3	113.3	116.2	109.4	1.83
ADG, lbe,f		1.96	1.92	2.08	1.78	.05
ADFI, lb[e]		4.95	4.75	5.13	4.67	.12
Gain/feed[f]		.40	.41	.41	.38	.01
Phase 2						
Final wt., lb[d,f]		241.1	245.8	239.2	222.8	4.83
ADG, lb[d]		1.84	1.89	1.76	1.62	.06
ADFI, lb[d]		5.54	5.63	5.17	5.09	.14
Gain/feed		.33	.34	.34	.32	.01
Overall						
ADG, lb[d,f]		1.87	1.90	1.85	1.67	.05
ADFI, lb[d]		5.37	5.38	5.16	4.97	.12
Gain/feed[f]		.35	.35	.36	.34	.01

[a]ADG = average daily gain, ADFI = average daily feed intake, and gain/feed = feed efficiency.
[b]INTACT = corn-soybean meal diet; IDEAL = corn-soybean meal-amino acid supplemented diet.
[c]Standard error of the mean.
[d]Diet effect, P < .05.
[e]Sex effect, P < .05.
[f]Diet x sex interaction, P < .05.

Table 4. Carcass weight and characteristics of barrows and gilts consuming intact corn-soybean meal and ideal protein diets[a].

Item	Diet, Sex,	INTACT[b]		IDEAL[b]		SEM[c]
		Gilts	Barrows	Gilts	Barrows	
No. of pigs		8	9	9	6	
Carcass wt., lb[d,f]		181.0	185.5	180.8	170.4	3.60
Ham wt, lb		17.9	17.7	18.6	16.0	.74
Loin wt, lb		23.5	23.9	23.8	23.4	.55
Shoulder wt, lb[e,f]		23.5	23.3	23.9	21.4	.60
Primal cut wt/carcass wt, %		35.8	35.0	36.6	35.7	1.24
Lean, % of carcass wt[g]		45.8	45.9	46.4	45.8	1.06

[a]All carcass characteristics were determined using Total Body Electrical Conductivity (TOBEC). Individual carcass data were obtained from Sioux-Preme Packing; Sioux Center, IA.
[b]INTACT = corn-soybean meal diet; IDEAL = corn-soybean meal-amino acid supplemented diet.
[c]Standard error of the mean.
[d]Diet effect, P < .05.
[e]Sex effect, P < .05.
[f]Diet x sex interaction, P < .1.
[g]5% fat basis.

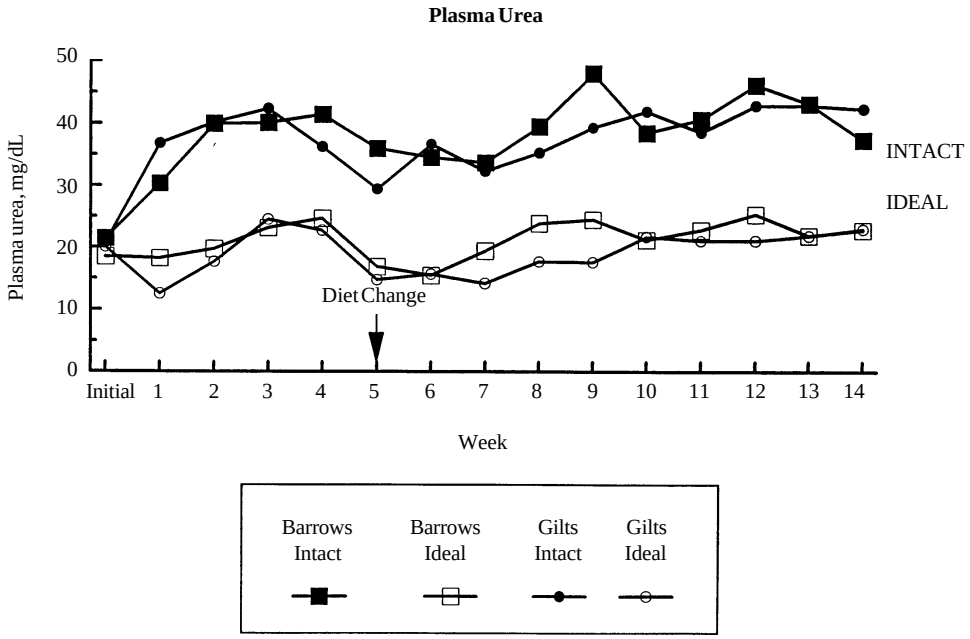

Figure 1. The response of plasma urea in barrows and gilts consuming corn-soybean (INTACT) or corn-soybean meal-amino acid supplemented (IDEAL) diets during a 14-week growing-finishing period.

actions (P < .1) observed for carcass and shoulder weight were due to the low values observed for the barrows receiving the IDEAL diet. For barrows, carcass weight was eight percent lower in the IDEAL vs INTACT diets. Diet did not affect any of the other carcass characteristics evaluated. Although growth rate was reduced in barrows vs gilts consuming the IDEAL diet (see Table 3), there was a numerical decrease in the carcass lean percentage of the barrows (barrows, 45.8%; gilts 46.4%).

Conclusions

Growth performance was not affected in gilts receiving IDEAL vs INTACT diets during the growing-finishing period. Although attempts were made to pair-feed barrow to gilts, the decreased feed efficiency of the barrows consuming the IDEAL diets resulted in reduced ADFI and ADG compared to gilts. However, we recognize that the pair-feeding regimen may have accentuated differences in growth performance between barrows and gilts consuming the IDEAL diets. Plasma urea concentration during the growing-finishing period was reduced in pigs consuming the IDEAL diet. There did not seem to be differences in plasma urea concentration between barrows and gilts receiving either diet.

[1]Phillip S. Miller is an Assistant Professor, Austin J. Lewis is a Professor, Cynthia K. Wolverton is a Research Technologist, and Christopher A. Borland is an Undergraduate Student.

Epinephrine and Energy Mobilization by Lactating Sows

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Summary and Implications

Research was conducted to determine the optimal dosage of epinephrine (adrenalin) for use as an in vitro diagnostic tool to measure changes in the mobilization of energy from body tissues. Doses of epinephrine were .1, .2, .4, .8, 1.2, and 1.6 µg/kg of body weight. Blood samples were collected from 15 minutes before epinephrine infusion through 120 minutes post infusion. Samples were analyzed for nonesteri-fied fatty acid (NEFA) and glucose content. Linear increases in NEFA and glucose were found for increasing dosages of epinephrine, along with a quadratic effect for some of the NEFA data because of a hypersensitive response to epinephrine at the lowest two levels. These data, although not establishing an optimal dosage of epinephrine, have shown that the lactating sow is capable of responding to increasing concent rations of epinephrine by increasing energy mobilization from body tissues and that the dosages of epinephrine used were insufficient

to induce maximal energy mobilization from peripheral tissues.

Introduction

The epinephrine (adrenalin) challenge has been successfully used in cattle to examine changes in the ability to mobilize energy from body stores. This is due to the classical "fight or flight" response that animals exhibit when frightened. Epinephrine is the principal hormone involved with this type of response, and it is responsible for large amounts of energy being mobilized to respond to perceived threats. However, to date, the epinephrine challenge has seen limited use in swine, and the optimal dosage has not been determined for use with the lactating sow.

The objective of this experiment was to determine the optimal dosage of epinephrine needed to examine the ability of the lactating sow to mobilize energy from body stores. This was done with the goal of subsequently using the epinephrine challenge to detect diet-induced differences in the ability of the lactating sow to mobilize energy during lactation.

Procedures

Six first parity crossbred sows were used to determine the optimal dosage of epinephrine. Sows received approximately 4 lb/d of a standard diet through d 110 of gestation. On d 110, sows were moved to farrowing crates. Sows were fed 4 lb/d of a 1% lysine corn-soybean meal diet (Table 1) until farrowing and had *ad libitum* access to the same diet after parturition. Nutrient concentrations in this diet exceeded National Research Council requirements. Farrowing room temperature was maintained at 70°F, and there was continuous lighting. Sow and litter weights were recorded on a weekly basis from d 0 (within 24 hours postfarrowing) to d 23 (weaning). Feed intake was determined on a daily basis for 23 days.

Sows were fitted with two jugular catheters on d 110 of gestation. Catheters consisted of medical grade tubing inserted into the sow through an ear vein.

Table 1. Composition of diet

Ingredient	Percent
Corn	67.90
Soybean meal (46.5% CP)	28.00
Limestone	.40
Dicalcium phosphate	2.10
Salt	.50
Vitamin premix	1.00
Trace mineral premix	.10
Formulated composition	
Protein, %	18.50
Metabolizable energy, Mcal/lb	1.46
Lysine, %	1.00
Calcium, %	.90
Phosphorus, %	.75
Analyzed composition	
Dry matter, %	89.29
Protein, %	18.95
Fat, %	2.81
Ash, %	5.46
Calcium, %	.93
Phosphorus, %	.76

Table 2. Sow and litter performance

Criteria	Low	Mean[a]	High
Sow feed intake, lb/d d 0 to 23	4.81	9.63	12.79
Sow weight loss (-) or gain (+), lb d 0 to 23	-54.78	-24.02	+5.06
Litter size at birth	9	10.67	12
Litter size at d 23	6	8.17	10
Litter weight at birth, lb	28.75	33.43	41.05
Litter weight gain, lb d 0 to 23	29.83	82.47	132.92

[a]Average performance of six sows and litters.

The experimental design was a replicated 6 x 6 Latin square. Sows were randomly assigned to receive each of six doses of epinephrine on d 3 to 8 and on d 17 to 22 of lactation. Dosages of epinephrine used were .1, .2, .4, .8, 1.2, or 1.6 µg/kg body weight. Blood samples were collected from these animals starting at 9:45 a.m., with epinephrine infusion occurring at 10:00 a.m. Collection times were -15, -5, 0 (immediately prior to infusion), 2, 4, 6, 8, 10, 15, 20, 25, 30, 45, 60, and 120 minutes after epinephrine infusion.

Plasma was analyzed for glucose and nonesterified fatty acids (NEFA). Peak height, adjusted peak height, and area under the curve were then calculated daily for each sow. Peak height consisted of the average of the 8, 10, and 15 minute samples, while the adjusted peak height was corrected for differences in baseline concentration of the metabolite (i.e., peak concentration - baseline concentration). Baseline concentration was determined by averaging the values obtained before epinephrine infusion. Response area was calculated from 0 to 45 minutes after epinephrine infusion. This was done by averaging values obtained from consecutive time points, and multiplying the average by the time elapsed between data points. These values were then summed over the 45-minute period.

Results and Discussion

(Continued on next page)

Table 3. Plasma metabolite concentrations

	Epinephrine dosage, µg/kg						P≤	
Criteria	.1	.2	.4	.8	1.2	1.6	L[a]	Q[a]
NEFA[b]								
Baseline, µEq/L	213.0	128.5	114.4	144.3	106.9	180.9	NS[c]	NS
Peak, µEq/L	248.4	157.5	137.7	185.8	188.1	295.5	.11	.05
Adjusted peak, µEq/L[d]	36.6	28.9	23.3	41.4	81.1	114.5	.01	NS
Response area, µEq L^{-1}•min^{-1}	1,458.7	856.2	697.5	1,112.5	1,844.4	2,628.1	.01	.06
Glucose								
Baseline, mg/dL	84.1	82.7	85.6	85.0	89.7	77.5	NS	NS
Peak, mg/dL	84.8	91.6	87.5	97.5	108.9	103.5	.01	NS
Adjusted peak, mg/dL[d]	0.0	8.3	0.3	11.7	23.0	27.7	.01	NS
Response area, mg dL^{-1}•min^{-1}	274.9	365.0	317.2	417.0	569.1	860.2	.01	NS

[a]L = linear, Q = quadratic.
[b]NEFA = nonesterified fatty acid.
[c]NS = not significant, P > .10.
[d]Adjusted peak is the peak concentration adjusted for baseline concentration of zero (i.e., peak - baseline).

There was a limited number of sows in this study, and sow and litter performance was quite variable (Table 2). These data are included primarily to aid in interpretation of the metabolite responses.

No differences were observed in baseline concentrations of NEFA or glucose among dosages of epinephrine (Table 3). This was expected because epinephrine is metabolized rapidly, therefore the previous dosage should not affect baseline concentrations on the next day.

Peak NEFA concentration in plasma exhibited a quadratic response ($P < .05$) to epinephrine dosage, with a decline from the .1 μg/kg dosage to the .4 μg/kg dosage, followed by increases in NEFA concentration to the 1.6 μg/kg dosage. When adjusted for baseline, peak height increased linearly ($P < .01$), suggesting that variation in baseline concentration (although not significant) was contributing to the quadratic effect observed with the unadjusted peak concentrations. Response area for NEFA increased linearly ($P < .01$) with some tendency ($P < .06$) for a quadratic response to increasing doses of epinephrine, following a pattern similar to that observed for peak height.

Peak glucose concentration increased linearly with increasing dosage of epinephrine ($P < .01$). This was also observed for the adjusted peak concentration ($P < .01$) and the glucose response area ($P < .01$). These data show that the sow responds to increasing dosages of epinephrine by increasing glucose release into plasma from glycogen stores and from increased gluconeogenesis.

Conclusions

The lactating sow is able to increase energy mobilization from body tissues in response to administration of increasing dosages of epinephrine. The optimal dosage of epinephrine was not established. This experiment has shown that the optimal dosage is higher than the dosage used previously in sows or the optimal dosage for the dairy cow (.4 μg/kg).

[1]Scott L. Tilton and Paul M. Ermer are graduate students, Austin J. Lewis is a Professor, Phillip S. Miller is an Assistant Professor, and Cynthia K. Wolverton is a Research Technologist, Department of Animal Science.

The Effects of Tallow Addition to the Diets of Lactating Sows on Hormone and Metabolite Concentrations

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Austin J. Lewis
Cynthia K. Wolverton[1]

Summary and Implications

The metabolic responses of sows fed a corn-soybean meal or a corn-soybean meal-10% tallow diet were measured. The addition of tallow to lactating sows diets had no effect on feed or energy intake. In addition, there were no effects on the concentrations of glucose, nonesterified fatty acids (NEFA), insulin, or glucagon. No differences in either the time spent consuming feed or the number of meals consumed were observed. Finally, no linear association between eating time and area under the curve for insulin was observed for sows consuming either diet. These results show the addition of tallow to lactation diets does not affect the concentrations of glucose, NEFA, insulin or glucagon in the fed state.

Introduction

In previous research (Nebraska Swine Report, 1995) we have reported several behavioral and physiological responses to the addition of tallow to lactating sow diets. Although there were no differences in feed or energy intake, the addition of tallow resulted in increased rate of feed consumption and decreased the percentage of time spent consuming feed. Fasting concentrations of glucose were increased and nonesterified fatty acids (NEFA) and glucagon were decreased in sows fed the tallow diet.

The objective of the following experiment was to measure changes in feed and energy intake and meal patterns associated with the addition of tallow to lactation diets. In addition, nonfasting (fed) concentrations of hormones and metabolites were measured.

Methods

Eight first-litter crossbred gilts were used. Gilts were randomly and equally allotted within room (two rooms) to receive either a corn-soybean meal (C-SBM) or a corn-soybean meal-10% tallow diet (Tallow, Table 1). Dietary treatments were initiated after parturition. Sow weight postpartum averaged 389 lb. Farrowing room temperature averaged 72° F and continuous lighting was provided. Sow and litter weights were obtained after parturition and on d 21 of lactation. Feed intake was

Table 1. Diet composition (as-fed basis)[a]

Ingredient, %	C-SBM	Tallow
Corn	67.90	56.80
Soybean meal, 46.5%	28.00	29.00
Dicalcium phosphate	2.10	2.30
Salt	.50	.50
Limestone	.40	.30
Vitamin mix	1.00	1.00
Trace mineral mix	.10	.10
Tallow	——	10.00
Formulated composition		
Metabolizable energy, Mcal/lb	1.48	1.69
Crude protein, %	18.8	18.3
Lysine, %	1.02	1.02
Calcium, %	.88	.89
Phosphorous, %	.76	.77

[a]Diets are corn-soybean meal (C-SBM) and corn-soybean meal-10% tallow (Tallow).

measured daily for 21 days. Litter size was standardized within 3 days of parturition.

On d 7 and 21 of lactation, meal patterns were measured continuously from 6:00 a.m. to 2:00 p.m. Sows were considered to be feeding when observed chewing with their head in the feeder. Meals were considered to be periods of feeding separated by at least 20 minutes. All feeding periods meeting this criterion were considered to be meals.

Catheters were inserted into the vena cava to enable frequent blood collection. Blood was collected every 15 minutes from 6:00 a.m. to 2:00 p.m. on d 7 and 21 of lactation. Plasma was separated and analyzed for insulin, glucagon, glucose, and NEFA.

Average hormone and metabolite concentrations were calculated from values obtained at all time points. Areas under the curve (AUC) for insulin are the sum of the average concentrations of two consecutive samples multiplied by the elapsed time. All samples collected on d 7 and 21 were used to calculate AUC for insulin.

Data were analyzed as a randomized complete block. Because of catheter failure, one sow each on d 7 and 21 was not included in the data set.

Results

There were no differences in feed or energy intake (Figure 1). Numerically, both feed and energy intake were lower (23 and 10%, respectively) in sows fed the Tallow diet than in sows fed the C-SBM diet.

Because of the small number of sows on each treatment, sow and litter performance was averaged across treatments. These data are included to aid in interpretation of hormone and metabolite responses. On average, sows lost 39.3 lb during lactation. Litter weight gain averaged 109.1 lb and litter size at weaning was 9.7 pigs.

No differences in the time spent consuming feed or the number of meals consumed were observed (Table 2).

Average concentrations of glucose or NEFA were not affected by diet (Table 3). Glucose concentrations decreased from d 7 to 21 in sows fed both diets (P = .01). Although there was no effect of day of lactation on NEFA

(Continued on next page)

Table 2. Meal patterns of gilts fed a corn-soybean meal (C-SBM) or a corn-soybean meal-10% tallow (Tallow) diet[a]

	Day 7		Day 21				
Criteria	C-SBM	Tallow	C-SBM	Tallow	P[b] (Diet)	P (Day)	SE[c]
No. of sows	3	4	4	3			
Time spent consuming feed, min	40.50	37.78	42.00	39.88	NS	NS	8.63
Number of meals consumed	3.25	4.88	4.00	4.13	NS	NS	.79

[a]Responses were measured from 6:00 am to 2:00 pm
[b]NS is not significant (P > .05)
[c]SE = standard error

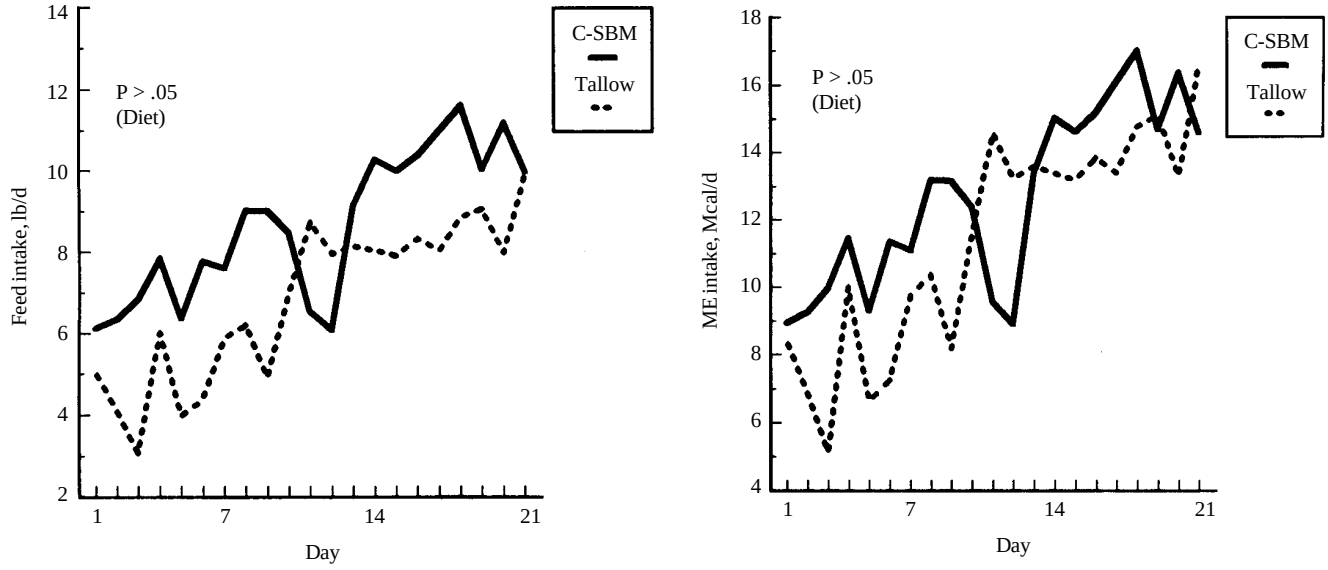

Figure 1. Feed and energy intake of sows fed either a corn-soybean meal (C-SBM) or a corn-soybean meal-10% tallow (Tallow) diet.

Table 3. Average hormone and metabolite concentrations of gilts fed a corn-soybean meal (C-SBM) or a corn-soybean meal-10% tallow (Tallow) diet[a]

Criteria	Day 7		Day 21		P[b] (Diet)	P (Day)	SE[c]
	C-SBM	Tallow	C-SBM	Tallow			
No. of sows	3	4	4	3			
Glucose, mmol/L	5.24	5.39	4.55	4.90	NS	.01	.17
NEFA[d], uEq/L	415.92	703.53	352.22	418.50	NS	NS	82.99
Insulin, pmol/L	199.39	202.19	201.34	178.18	NS	NS	27.57
Glucagon, ng/L	68.17	67.88	65.24	78.73	NS	NS	9.71
Insulin:Glucagon, mol:mol	11.58	12.26	13.64	10.24	NS	NS	3.04

[a]Concentrations are averages of samples drawn every 15 min from 6:00 am to 2:00 pm
[b]NS is not significant (P > .05)
[c]SE = standard error
[d]NEFA is nonesterified fatty acids

concentration, there was a 37% decrease from d 7 to 21 of lactation. Average concentrations of insulin, glucagon, and the insulin:glucagon ratio were not affected by diet or day of lactation (Table 3).

No correlation was detected between AUC for insulin and time spent eating (r = .38, Figure 2).

Discussion

Feed and energy intake was lower in this experiment than in a previous experiment. Low feed and energy intakes were associated with increased sow weight loss.

Contrary to results of a previous experiment, no effect of diet on percentage of time spent consuming feed was observed. This may be due to the shorter period of time in which meal patterns were measured (8 versus 24 h).

Time spent consuming feed, when expressed as a percentage (8.3%), is similar to values reported previously over a 24-hour period. We expected the percentage of time spent consuming feed to be higher because previous research indicates that sows consume a larger proportion of meals during the day than at night.

There were several discrepancies in hormone and metabolite concentrations observed between this and a previous experiment. First, there were no effects of diet on average concentrations of glucose, NEFA, or glucagon in this experiment. Second, greater weight loss in the present experiment was associated with lower concentrations of glucagon and higher insulin:glucagon ratios. It is difficult to compare results of experiments where sows are in a fed versus a fasted state. Both feeding and energy balance affect hormones and metabolites in the fed state, whereas only energy balance affects hormones and metabolites in the fasted state. Whether hormone concentrations in the fed or fasted state are a better indicator of changes in metabolic status during lactation is unknown.

Average concentration of NEFA decreased from d 7 to 21 of lactation. This indicates a decrease in fat mobilization from body reserves as lactation progressed. The large sow weight losses during lactation indicate that body fat reserves may have been significantly depleted.

Several factors may have contributed to the low correlation between time spent feeding and AUC for insulin. First, time spent eating may not reflect feed intake across treatments. In a previous experiment, differences in rate of feed consumption were observed. Secondly, factors other than eating, such as energy balance, influence insulin concentration.

These results, and those of a previous experiment, indicate inconsistent responses in feed and energy intake to the addition of tallow to lactating sow diets. Changes in fasting hormones and metabolites previously observed in sows fed diets containing tallow were not observed in the fed state. Future work will examine hormone and metabolite profiles in response to feeding and investigate other metabolic signals that may influence feeding behavior or energy intake in lactating sows.

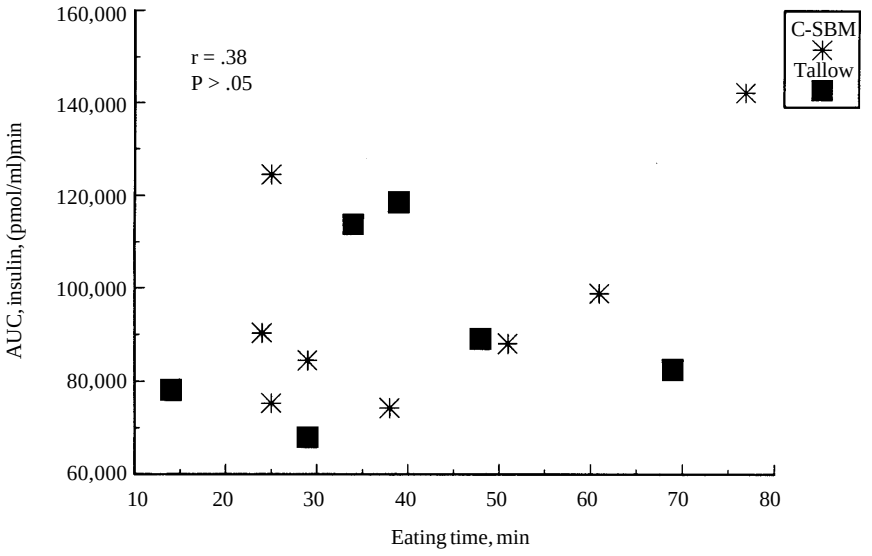

Figure 2. Correlation of area under the curve (AUC) for insulin to eating time for sows fed either a corn-soybean meal (C-SBM) or a corn-soybean meal-10% tallow (Tallow) diet.

[1]Paul M. Ermer and Scott L. Tilton are graduate students, 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.

Impact of Cooking Method on Quality of Boneless Pork Loin Roasts

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Roger W. Mandigo[1]

Summary and Implications

Chef's Prime™ pork loin roasts were roasted, braised and cooked in a bag at an oven temperature of 325°F to an internal temperature of 160 or 180°F. Roasting improved yield and surface browning of Chef's Prime™ roasts. While roasting and braising resulted in similar quality, the presence of moisture (braising and cook-in bag) reduced cooking time. Cooking in the bag had the greatest impact on quality characteristics as these roasts were least tender and they tended to be less juicy and favorable than braised or roasted loins. Reduction of the final internal temperature from 180 to 160°F did not improve yield or quality. Chef's Prime™ loin roasts can be enjoyed by all consumers when selection of cooking method and cooked quality match consumer need.

Introduction

Consumers across Nebraska and the nation select pork as a meat choice approximately 25 percent of the time. Yet comments persist about dry, flavorless pork. Early cookery practices included cooking fresh pork roasts to 180°F. In efforts to improve the eating quality of fresh pork, the National Live Stock and Meat Board in the early 1980s revised the final internal temperature for fresh pork products to 170°F. In 1988, the National Pork Producers Council (NPPC) revised the final internal cooked temperature recommendation for fresh pork cuts from 170°F to 160°F. A year later, NPPC trademarked the Chef's Prime™ loin roast. The consumption rate and subsequent NPPC changes demonstrate the need for revised quality information for Chef's Prime™ roasts. The primary objective of this research was to determine the influence of final internal temperature and cooking method on yield and quality characteristics of boneless Chef's Prime™ pork loin roasts.

Materials and Methods

Boneless pork loins were purchased, trimmed to 1/8-inch fat, cut according to NPPC specifications for Chef's Prime™ roasts, vacuum packaged and frozen. Three-lb frozen, roasts were tempered 48 hours at 40°F before being placed on a rack in an uncovered roasting pan (roast); placed on a rack in a roasting pan, 1.5 lb water added and tightly sealed with aluminum foil (braise); or placed in a retail cooking bag following manufacturer's recommendations and placed in a roasting pan (cook-in bag). Roasts were cooked at 325°F in a household range to two final internal temperatures (160, 180°F) and three cooking methods (roast, braise, cook-in bag). Four replications were completed.

The weight of each roast was recorded before and after cooking for determination of cooked roast yield (%). Total cooking time for the roasts to reach the appropriate internal temperature was recorded. Sensory quality characteristics were evaluated by an experienced, six-member panel. Tenderness, juiciness and pork flavor intensity were evaluated using a 15-unit unstructured line with 0 = very tough, very dry and lack of pork flavor and 15 = very tender, very moist and very intense pork flavor. Instrumental surface color (Labscan) of the cooked roasts, objective tenderness (Kramer Shear) and final product moisture retention measurements were completed.

Results and Discussion

Yields for boneless Chef's Prime™ pork loin roasts are presented in Table 1. At an oven temperature of 325°F, reducing final internal temperature from 180°F to 160°F did not result in significant yield differences. An oven temperature of 325°F may have been too hot and cooked the meat too rapidly. Subsequently, the anticipated yield differences expected when the internal temperature was lowered were not observed.

Yields tended to be greater for loins that were roasted than for loins that were braised or cooked in the bag (Table 1). Roasting increased moisture retained within the roasts. Roast-

(Continued on next page)

Table 1. Yield (%) for Chef's Prime™ boneless pork loin roasts cooked by three methods to two internal temperatures.

	Yield (%)[1,a]
Temperature	
160° F	72.6 ± 2.10
180° F	71.9 ± 2.10
Cooking method	
Roast	74.7 ± 2.42
Braise	71.2 ± 2.42
Cook-in bag	70.9 ± 2.42

[1]Values represent least square means and least square standard errors.
[a]Values within internal temperature and cooking method are not significantly different (P≤.05).

ing Chef's Prime™ loin roasts enhanced browning as a golden surface resulted. Surface browning of braised roasts did not develop as the pan was tightly covered with foil, while a minimal amount of surface browning resulted when roasts were cooked in the bag.

Final internal temperature and cooking method influenced cooking time (min/lb). Less time was required to cook Chef's Prime™ roasts to a final internal temperature of 160°F than to a final internal temperature of 180°F. Roasting to 160°F required 43.5 min/lb while roasting to 180°F required 54.6 min/lb. The presence of moisture--added in braising, or trapped in the cook-in bag—reduced cooking time. Mean cooking time was similar for braised and cook-in the bag roasts cooked to 160°F final temperature (35.8 min/lb for braised; 36.4 min/lb for cook-in bag). Braising to an internal temperature of 180°F required 40.22 min/lb while cook in the bag required 40.75 min/lb.

Cooking method influenced sensory tenderness. Roasted Chef's Prime™ loins were evaluated as more tender (P<.05) than loins that were cooked in a bag and were similar in tenderness to braised roasts (Table 2). Cook-in bag roasts were the least tender. Juiciness and pork flavor intensity ratings of Chef's Prime™ roasts were similar for all cooking methods. While sensory scores for cook-in bag roasts were not significantly different, roasts cooked in the bag were ranked as least juicy and lowest in pork flavor intensity. Use of a cooking bag appears to alter pork roasts sensory characteristics. Final internal temperature did not influence tenderness, juiciness and pork flavor intensity of the roasts.

Objective tenderness evaluations (Kramer Shear) are presented in Figure 1 and were influenced by cooking method and final internal temperature. Less total energy was required to mechanically shear braised loins than those cooked in a bag. Kramer Shear peak force (Newton) was less for loins that were roasted to 180°F than for loins roasted to 160°F (P<.05). No differences in Kramer Shear were observed for braised and cook-in bag loins. Maximum force required to shear was greatest for cook-in bag roasts and for loins roasted to 160°F.

Table 2. Sensory Panel Scores[1] for Chef's Prime™ boneless pork loin roasts cooked by three methods to two internal temperatures.

Item	Cooking method[2]			Final internal temperature[2]	
	Roast	Braise	Cook-In Bag	160°F	180° F
Tenderness	8.16 ± 0.89[a]	7.93 ± 0.89[a,b]	6.66 ± 0.89[b]	7.55 ± 0.85	7.61 ± 0.85
Juiciness	6.26 ± 0.95	6.19 ± 0.95	5.63 ± 0.95	6.12 ± 0.91	5.94 ± 0.91
Flavor intensity	6.64 ± 0.89	6.13 ± 0.89	5.78 ± 0.89	6.16 ± 0.46	6.21 ± 0.46

[1]0 = Very tough, very dry, lack of pork flavor; 15 = Very tender, very moist, intense pork flavor
[2]Values represent least square means and least square standard errors.
[a,b]Values for each sensory attribute within cooking method or final internal temperature sharing a common superscript are not significantly different (P≤.05).

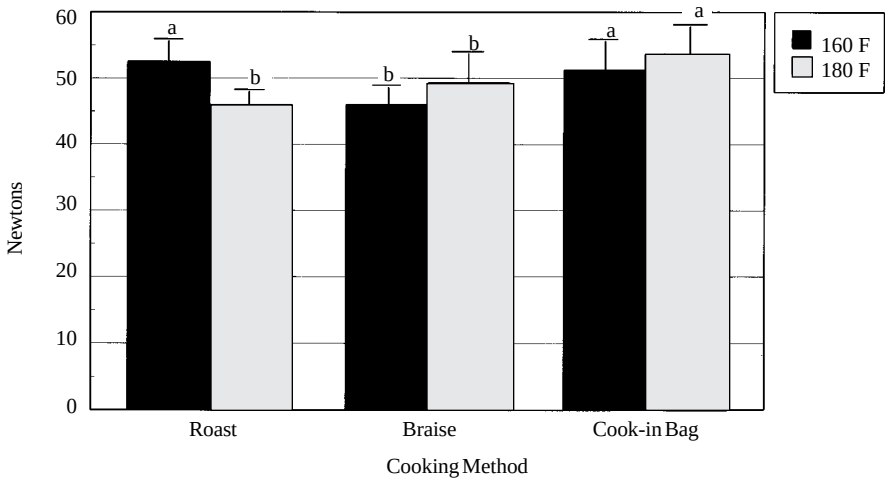

Figure. 1. Kramer peak force (newton) for pork loin roasts cooked by three methods to two internal temperatures. Values represent least square means and least square standard errors. Values for each cooking method sharing a common superscript are not significantly different (P≤.05).

Conclusions

A reduction in final internal temperature did not significantly improve yield or sensory tenderness, juiciness or flavor intensity of Chef's Prime™ loin roasts cooked at an oven temperature of 325°F. Cooking method did influence quality characteristics. Roasting Chef's Prime™ loin roasts enhanced surface browning and improved sensory tenderness. Cook-in the bag loin roasts tended to be less juicy and flavorful than braised or roasted loin roasts. Cooking Chef's Prime™ loin roasts in a bag decreased instrumental tenderness when compared to braised loin roasts.

Adding moisture to the cooking method and reducing final internal temperature shortened cooking time for braised and cook in the bag roasts. Roasting or braising Chef's Prime™ loin roasts is recommended when striving to enhance yield and quality characteristics.

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Gelatinized High Added-Water Pork Skin Connective Tissue Protein Gels as Potential Water Binders

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Roger W. Mandigo[1]

Summary and Implications

Heating pork skin connective tissue (PCT) obtained from pork carcasses may enhance its water binding ability due to partial conversion of connective tissue collagen to gelatin. Upon cooling, the protein gel partially reforms, and may entrap added water. Incorporation of this recovered protein as a high added-water gel in reduced-fat products may improve product juiciness and palatability. The objectives of this study were to determine temperature and time variables that enhance conversion of connective tissue collagen to gelatin and determine basic properties of high added-water pork skin connective tissue gels. Heating PCT at 158°F for 30 minutes released more gel-water indicating conversion of connective tissue to gelatin. Added water (AW) levels of 100, 200, 300, 400, 500 and 600% were used to determine the water binding ability of heated PCT. Soluble collagen of these gels ranged from 100 to 25 mg/g, allowing the production of stable protein gels with as much as 600% AW. Increasing added water levels softened gel texture and lightened gel color. The potential exists to incorporate high added-water PCT gels into reduced-fat pork products to enhance product attributes.

Introduction

Reduction of fat in processed meats causes problems with product toughness, texture, flavor, juiciness, and color. Regardless of how important diet and health issues are to consumers, reduced-fat products will not be purchased if they have unacceptable palatability or appearance. Current technologies for fat replacement include adding water, protein-based, carbohydrate-based, or synthetic compounds, alone or in combination. The addition and retention of water by these fat replacers is effective in improving the palatability attributes of reduced-fat meat products. Pork skin connective tissue (PCT), a by-product of pork fabrication operations, may be used as a potential water binder to replace fat in reduced-fat meat products. The mechanism for this improvement may lie in the thermal denaturation of collagen during heating and its conversion to gelatin, a water binding agent. This study consisted of two experiments. The objective of Experiment I was to determine temperature and time variables that enhance conversion of pork connective tissue to gelatin. The objective of Experiment II was to determine basic properties of high added-water pork connective tissue gels.

Procedures

Experiment I

Pork skin connective tissue (PCT) was obtained by removing the skin from the loin, shoulder and ham regions of pork carcasses of market weight (about 220 lb) hogs. The skins were hand-scraped with a boning knife to remove excess subcutaneous fat and cut into strips approximately two inches wide and ten inches long. The strips of skin were frozen, coarse ground, refrozen, and flaked in an Urschel Comitrol. The PCT samples were placed in tubes (three per temperature x time combination) which were heated in a water bath at a single temperature (122, 140, 158 or 176°F) and removed at a specified time period (0.5, 1.0, 1.5 or 2.0 hours). Fluids released from each sample were decanted into graduated tubes. Each temperature x time treatment combination was averaged and reported as mL released fluids per 100 g sample. The experiment was designed as a split plot with a 4 x 4 factorial arrangement of treatments. Water bath temperature was the whole plot factor and time period the split plot factor. The experiment was replicated twice (n = 32).

(Continued on next page)

Table 1. Treatment formulations for the manufacture of PCT gels (Experiment II).

Treatment	Connective Tissue	Added Water
1	250 g	250 g (100%)
2	167 g	334 g (200%)
3	125 g	375 g (300%)
4	100 g	400 g (400%)
5	83 g	415 g (500%)
6	71 g	426 g (600%)

Experiment II

The PCT described in Experiment I was used to determine its ability to form a gel and bind added water. Appropriate amounts of PCT and distilled, deionized water were combined in 600 mL beakers to produce PCT gels weighing about 500 g and containing 100, 200, 300, 400, 500 or 600% added water (AW) (Table 1).

Based on the results from Experiment I, PCT x water treatments were heated at 158°F for 30 min. To enhance the uniform dispersion of flaked PCT throughout the PCT gel matrix, the beakers were removed from the water bath, placed on stirring plates and mixed with stir bars in a refrigerated cooler (43±2°F) at high speed until the gels thickened. The pH of each PCT gel was determined. Samples were obtained from each PCT gel treatment and used for HunterLab Colorimeter analysis (Illuminant A, 2° standard observer). Readings for HunterLab L* (lightness), a* (redness), and b* (yellowness) values were taken. The textural parameters of hardness, cohesiveness, springiness and chewiness were also determined per gram of gel. Analysis for hydration, a measure of water binding, was determined by dividing the amount of water retained by the amount of connective tissue contained in the gel sample, which varied among treatments (Table 1) and was expressed as g water held/g wet tissue. Variability in total amount of PCT contained in each gel treatment was accounted for by expressing hydration on a fat-free basis. Cook stability was determined by placing samples into a 120°F water bath and gradually increasing the water bath temperature until the internal sample temperature reached 156°F within 1.25 to 1.50 hours. The free liquid was decanted and cook stability expressed on a sample percentage and fat-free PCT basis. The experiment was designed as a randomized complete block design with a single factorial (AW) treatment. The experiment was replicated three times (n = 18).

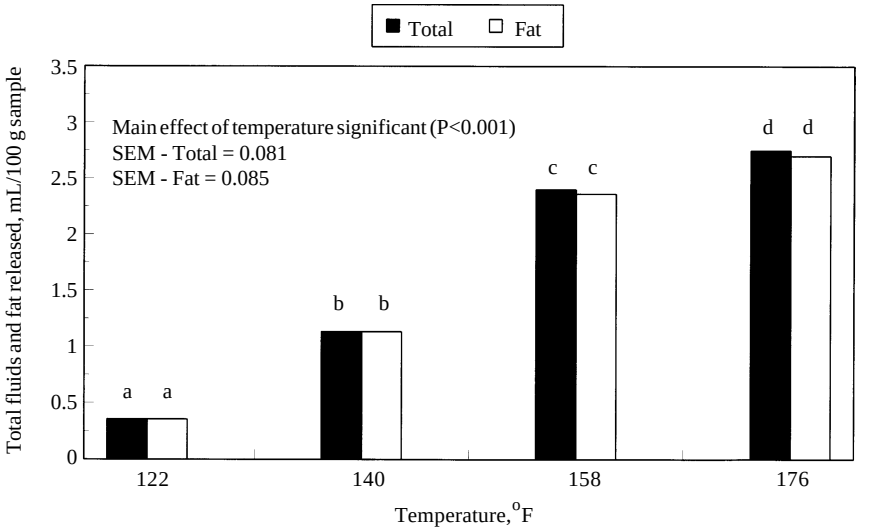

Figure 1. Main effect of temperature on total fluids and fat released from flaked, pork skin connective tissue heated at four temperatures. SEM = standard error of the mean.

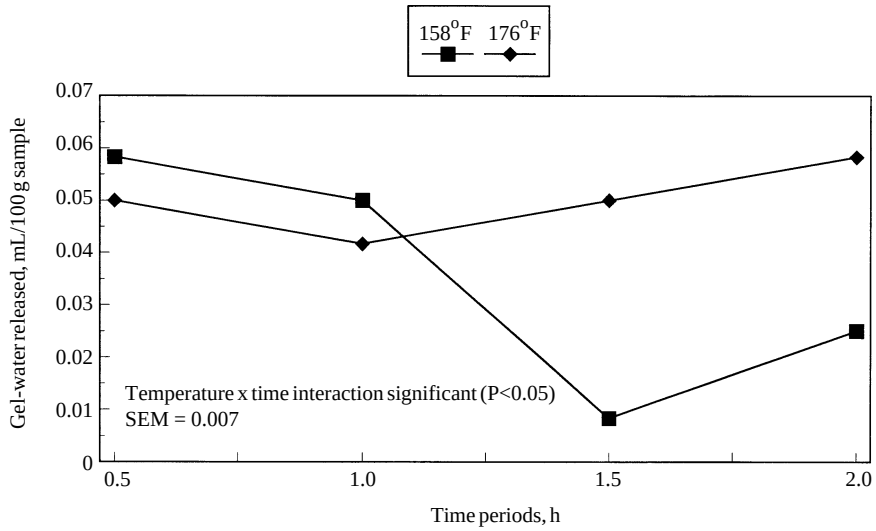

Figure 2. Lease squares means separation for released gel-water at 158 and 176°F within each time period for flaked, pork skin connective tissue. SEM = standard error of the mean.

Results and Discussion

Experiment I

The main effect of temperature increased (P<0.001) the volume of released total fluids and fat (Figure 1). A temperature x time interaction (P<0.05) existed for PCT for released gel-water (Figure 2). No gel-water was released at 122 or 140°F, indicating that these temperatures where not high enough to cause solubilization of pork skin connective tissue collagen to gelatin. Volumes of released gel-water were similar for PCT heated at 158 and 176°F, indicating solubilization of collagen to gelatin. Similar volumes of gel-water was released by PCT at 0.5 h for 158 and 176°F and at 1.5 and 2.0 h for 176°F (Figure 2). The observed decrease in released gel-water at 158°F as time periods increased may be due to the binding of water by solubilized connective tissue, thereby lowering the

Table 2. Proximate composition, soluble collagen content, hydration, and cook stability for high-added water pork connective tissue gels.

		Added Water Treatments (%)					
	SEM	100	200	300	400	500	600
Proximate composition (%)							
Moisture	0.66	71.33^{e}	80.47^{d}	86.81^{c}	89.62^{b}	90.40^{b}	92.81^{a}
Fat	0.56	12.17^{a}	6.90^{b}	4.30^{c}	3.89^{cd}	2.52^{de}	1.67^{d}
Protein	0.45	14.31^{a}	10.37^{b}	8.40^{c}	6.91^{d}	5.38^{e}	4.68^{e}
Collagen content (mg/g)							
Soluble	4.22	101.86^{a}	72.41^{b}	51.15^{c}	39.10^{cd}	32.92^{de}	23.46^{e}
Hydration (g H_2O held/g tissue)							
Sample	0.010	0.99^{ab}	2.02^{a}	2.95^{b}	3.89^{c}	4.79^{c}	5.53^{d}
Fat-free basis	0.016	1.13^{f}	2.17^{e}	3.09^{d}	4.04^{c}	4.92^{b}	5.63^{a}
pH	0.39	7.42^{c}	7.53^{bc}	7.69^{a}	7.61^{ab}	7.67^{a}	7.68^{a}
Cook stability (%)							
Sample	3.55	88.16^{a}	79.00^{a}	49.78^{b}	33.16^{c}	28.16^{c}	26.47^{c}
Fat-free basis	3.58	93.87^{a}	80.85^{b}	50.32^{c}	33.42^{d}	28.28^{d}	26.53^{d}

$^{a-e}$Means within row with different superscripts are different (P<0.05).

Table 3. Color values and textural attributes for high-added water pork connective tissue gels.

		Added Water Treatments (%)					
	SEM	100	200	300	400	500	600
Color							
Lightness (L*)	0.96	65.83^{b}	72.78^{a}	66.85^{b}	62.28^{c}	60.09^{c}	59.45^{c}
Redness (a*)	0.15	4.09^{a}	3.32^{b}	1.39^{c}	-0.32^{d}	-0.58^{e}	-1.19^{f}
Yellowness (b*)	0.27	10.77^{a}	10.03^{a}	6.63^{b}	4.29^{c}	2.17^{d}	0.80^{e}
Textural attributes							
Cohesiveness/g	0.013	0.112	0.093	0.084	0.074	0.067	0.071
Hardness (N/g)	3.08	136.62^{a}	76.72^{b}	41.98^{b}	22.02^{b}	13.55^{de}	7.68^{e}
Springiness (mm/g)	0.251	4.24	4.71	5.49	4.98	5.26	4.97
Chewiness (J/g)	3.025	64.53^{a}	34.32^{b}	20.30^{c}	8.19^{d}	4.93^{d}	2.98^{d}

$^{a-e}$Means within row with different superscripts are different (P<0.05).

amount of gel or water released from the PCT sample. Based on the results of Experiment I, it was concluded that heating PCT at a temperature of 158°F for approximately 30 min is sufficient to convert collagen to gelatin, thereby enhancing its potential capacity to bind added water.

Experiment II

Added water (AW) decreased (P<0.05) percent fat and protein, and increased moisture content (Table 2). Percentages ranged from 12.17 to 1.67% (fat), 14.31 to 4.68% (protein) and 71.33 to 92.81% (moisture), for 100 and 600% AW, respectively. The addition of water affected gel pH (P<0.05) with values ranging from 7.42 to 7.69. Increasing water decreased (P<0.05) soluble collagen content, with values ranging from 101.86 to 23.46 mg/g (100 and 600% AW, respectively). As AW increased, the amount of water bound (hydration) increased (P<0.05) from 0.99 (100 and 200% AW) to 5.53 (600% AW) grams of water held per gram of gel tissue. Expressed on a fat-free basis, hydration values ranged from 1.13 to 5.63 grams of water held per gram of PCT. Cook stability values decreased (88.16 to 26.47%) for 100 and 600% AW treatments, respectively, indicating solubilization of gelatin and subsequent release of water (Table 2).

Higher AW increased (P<0.05) L* (lightness) for 100, 200 and 300% AW treatments, but decreased for the remaining gel treatments (Table 3). Values for a* (redness), and b* (yellowness) decreased (P<0.05) as AW increased. Added water decreased (P<0.05) hardness and chewiness values per gram of gel, with 100% AW treatment approximately two times harder (136.62 N) than 200% AW treatment (76.72 N). Added water had no effect on cohesiveness or springiness. Springiness values ranged from 5.49 (300% AW) to 4.24 mm per gram (100% AW), while cohesiveness values ranged from 0.11 (100% AW) to 0.07 (600% AW) per gram (Table 3).

Based on the results from Experiment II, heating PCT allowed the production of high added-water protein gels. Softer texture, lighter color and ability to hold almost six times its weight in added water (hydration) and retain as much as 50 to 90% of this added water after reheating (cook stability) was observed for gels containing 100 to 300% AW. These functional properties may enhance overall product attributes if these protein gels are incorporated into reduced-fat products.

Results from this study indicate the feasibility of heating recovered pork connective proteins to form protein gels capable of binding large amounts of added water. The mechanism for this increase in water binding capacity appears to be due to the large amount of soluble collagen (gelatin) contained in these gels. Improvements in texture, color and palatability may result from the addition of gelatinized pork skin connective tissue protein gels into reduced-fat pork products. Additionally, economic benefits may be realized by using pork skin connective tissue protein gels to replace a percentage of the expensive lean tissue required for many reduced-fat pork products.

[1]Wesley Osburn, graduate student; Roger Mandigo, Professor, Animal Science, Lincoln.

House Mouse Damage to Insulation

Scott E. Hygnstrom[1]

Summary and Implications

House mice (Mus musculus) were introduced into 20, 4-inch thick insulated panels and provided unlimited food and water for six months. Mouse populations increased 3-to 4-fold inside the insulated panels. Aluminum foil vapor barriers were severely damaged by mice and in all cases, reduced to less than half of their original mass. All of the insulation materials tested (insulation board, fiberglass batt, rockwool, beadboard, and vermiculite) sustained significant levels of damage as measured by increased thermal conductance. Researchers have yet to discover an insulative material that is not susceptible to house mouse damage. Producers should use construction techniques that exclude house mice and other rodents from insulated walls. In addition, house mouse populations in and around buildings should be controlled to minimize economic damage.

Introduction

House mice are a common pest in both rural and urban areas around the world. They cause significant economic losses by consuming and contaminating livestock feed, reducing the structural integrity of buildings and equipment, and transmitting diseases to livestock and humans. In 1987, it was estimated that house mice and Norway rats (*Rattus norvegicus*) caused $8 million damage to grain and livestock feed and $8.4 million to agricultural buildings in Nebraska annually. In a 1983 survey of 275 Nebraska pork producers, 92 percent reported that house mice were present on their farms. Fifty-five percent of the producers reported having at least one insulated livestock confinement building and 67 percent experienced structural damage caused by house mice or Norway rats.

Insulation is often used in wall spaces of swine production facilities to reduce heat loss by thermal conductance and convection. When house mice gain access to insulated wall spaces, they construct tunnels and nests, resulting in the compaction, destruction, and removal of insulation. The resulting heat loss in confinement buildings can lead to higher heating costs and may necessitate costly reinstallation of insulation.

There is a continuing need to identify insulative materials that are more or less susceptible to rodent damage. Therefore, an experiment was conducted to determine the effects of house mouse activity on five different types of insulation. In addition, the changes in house mouse populations and their impact on an aluminum foil vapor barrier after they inhabited insulated panels for a 6-month period was evaluated.

Materials and Methods

The study was conducted at the University of Nebraska-Lincoln Veterinary Science Research Facility. Four rodent-proof rooms were subdivided with 22-gauge galvanized sheet metal into five, 6-foot x 3-foot x 2-foot high enclosures. Enclosures were installed to maintain 20 separate mouse populations.

One insulated wall panel (4-foot x 4-foot x 4-inches thick) was placed upright in each enclosure. The panels were built to simulate the wall of a controlled-environment livestock facility. Frames were made of 4-foot long 2-inch x 4-inch wooden studs on 16-inch centers. A 1/2-inch plywood sheet was nailed to the "inside" face of each frame and ribbed steel siding was nailed to the "outside" face of each frame. Three 3/4-inch-diameter holes were drilled through the bottom of the "inside" face of each panel to provide mice access to the panel cavities. A vapor barrier, consisting of a 2-foot x 4-foot piece of 5-mil aluminum foil weighing 40.0 g was attached to the inside of each plywood sheet. Four sets of 4 panels were each filled with one type of insulation, including: 1) Styrofoam® beadboard (Dow Chemical Co., Inc.), 2) fiberglass batt (Owens-Corning Fiberglas® Corp.), 3) rockwool (American Rockwool Corp.), and 4) vermiculite (W. R. Grace Co., Inc.). A fifth set of four panels was insulated with sheets of 1-inch Celotex® Tuff-R (Celotex® Co., Inc.), attached just inside the plywood sheet. One panel of each of the treatments was randomly assigned to an enclosure in each of the four rooms.

Two adult male and three adult female house mice were released into each enclosure and maintained for six months. All released mice were ear-tagged for individual identification. During the first 14 days, 15 dead mice were replaced with live mice of the same sex. After day 14, each population was allowed to fluctuate without additions, other than births, and without removal, other than deaths or escapes. Mice were provided unlimited

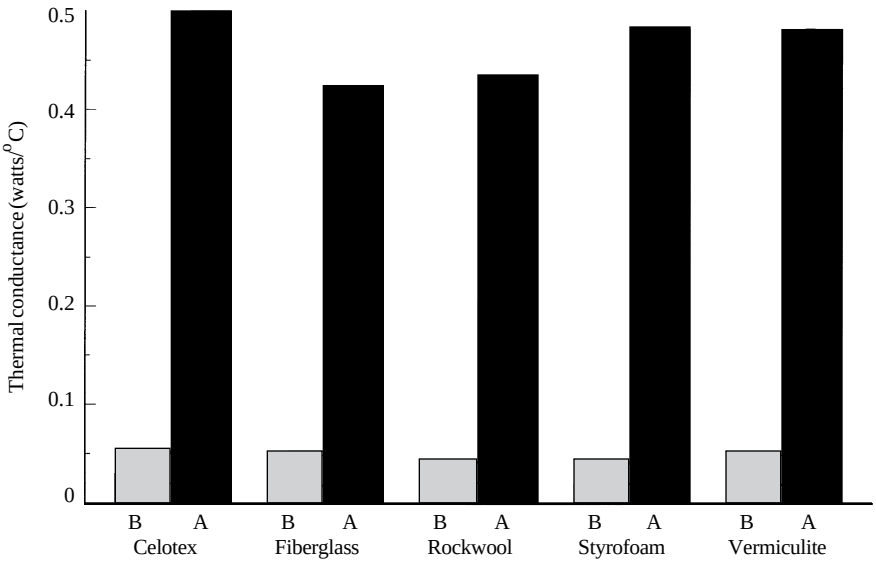

Figure 1. Mean thermal conductance (watts/^{o}C) of insulated wall panels (n = 20) before (B) and after (A) a 6-month occupation by house mice.

Figure 2. House mouse damage to a panel insulated with fiberglass batt after 6 months of exposure.

food (Wayne Rodent Lab-blocks) and water throughout the experiment. Enclosures were vacuumed two times per week to remove discarded insulation, waste food, excrement, and dead mice. Dead mice were identified and recorded throughout the 6-month period.

All mice were removed from the enclosures using live-traps at the end of the 6-month period. Mice were identified as tagged or untagged, counted, and euthanized with carbon dioxide gas. The remaining aluminum vapor barriers were removed and weighed at the end of the 6-month period. A heat flow probe (HFP-20, Concept Engineering) was used to measure the heat flow through the panels before and after they were subjected to house mouse activity. A temperature gradient was established "inside" and "outside" of each panel using an air conditioned cooling chamber. Temperatures ranged from 35 to 70^{o}F.

Results and Discussion

House mouse populations

The number of house mice in all panels combined increased from 100 to 399 during the 6-month period. During the study 172 dead mice were found and 227 mice were live-trapped at the end of the study. No significant differences were observed in the mean numbers of house mice found among the five types of insulation tested.

Vapor barrier damage

The integrity and function of the vapor barriers were significantly impaired by the house mice during the occupation period. The aluminum foil sheets were severely torn, shredded, and gnawed upon. Entire sections were missing in several cases. Mean weights of the vapor barriers that remained after the 6-month period were similar among treatments, but were dramatically less than the original 40.0 g vapor barriers that were installed. The damaged vapor barriers would be ineffective at inhibiting movement of moisture from the interior plywood wall to the insulation.

Insulation damage

House mouse activity during the 6-month period caused an increase ($P<.01$) in the heat flow and resultant thermal conductance through all five insulation types (Figure 1). The damage was quite obvious (Figure 2) and equally severe among the insulation types as there were no significant differences in thermal conductance.

To date, all insulation materials tested at the University of Nebraska and elsewhere have been susceptible to damage by house mice. Research should be conducted to develop and test insulative materials that are less attractive to house mice or less susceptible to house mouse activity.

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Effect of Floor Space Allocation on Barrow Performance to 300 Pounds

Mike Brumm
Jim Dahlquist[1]

Summary and Implications

One hundred eighty barrows (12/pen) were given space allocations of 7, 9, and 11 ft²/pig from 43 to 300 lb. There was no effect of space allocation on daily feed intake, lean gain, or carcass backfat depth. Pigs given 9 ft² grew fastest while pigs given 7 ft² had the best feed conversion. Daily gain and feed efficiency were worst when pigs were given 11 ft²/pig. Results from this experiment will be useful to producers as they make space allocation decisions for pigs finished at weights heavier than the current U.S. average of 245 to 250 lb.

Introduction

Average sale weights of butchers to U.S. packers are increasing. The average market hog sale weight for farrow-finish cooperators on the Iowa State University Swine Enterprise Records program in 1985 was 233 lb. In 1994, cooperators on the Iowa and Nebraska Enterprise program reported a sale weight of 246 lb.

Space recommendations for growing-finishing pigs usually suggest 8 ft² per pig to market weight. However, the optimum space allocation for pigs raised to heavy weights is unknown. With many producers currently having average sale weights approaching 270 lb, an experiment was designed to investigate the effects of space allocation to a final weight of 300 lb.

Table 1. Effect of floor space allocation on pig performance.

	Floor space (ft²/pig)			P values	
Item[a]	7	9	11	Linear	Quadratic
No. pens	5	5	5		
Pig weight, lb					
Initial	43.0	43.1	43.2		
29 d	92.4	92.0	90.6	< .075	NS[b]
99 d	233.6	237.6	229.2	< .1	<.05
Final	298.8	301.3	296.6	NS	NS
CV, within pen wt	8.2	6.9	7.9	NS	< .1
ADG, lb/d					
0 to 29 d	1.71	1.69	1.64	< .05	NS
0 to 99 d	1.93	1.96	1.88	< .1	< .05
Overall	1.85	1.89	1.82	NS	< .1
ADFI, lb/d					
0 to 29 d	3.28	3.31	3.26	NS	NS
0 to 99 d	5.35	5.50	5.31	NS	< .05
Overall	5.76	5.93	5.83	NS	NS
Feed/gain					
0 to 29 d	1.92	1.96	1.99	NS	NS
0 to 99 d	2.78	2.80	2.82	NS	NS
Overall	3.11	3.15	3.21	< .075	NS
Carcass last rib midline					
backfat depth, in	1.31	1.36	1.35	NS	NS
Lean gain, lb/d[c]	.65	.66	.65	NS	NS

[a]CV = coefficient of variation, ADG = average daily gain, ADFI = average daily feed intake, and Feed/gain = feed efficiency.
[b]NS = not significant (P > .1)
[c]5 % fat basis.

Experimental Procedure

One hundred eighty barrows were purchased from a single source. At arrival, all pigs were weighed, eartagged, and assigned to experimental space allocations on the basis of five weight outcome groups. Within outcome group, barrows were randomly assigned to the space allocation treatments of 7, 9, or 11 ft²/pig.

There were 12 pigs per pen and the space occupied by the feeder was subtracted from the total pen space in the determination of space treatments. If a pig died or was removed during the experiment, pen size was adjusted to maintain the correct space allocation per pig. Pigs were individually re-

moved for slaughter during the week that they weighed 300 lb or greater and pen size was not adjusted thereafter.

Pigs were housed in a fully slatted, naturally ventilated, confinement facility. Each pen contained a two-hole self feeder and two nipple drinkers. Sprinklers were used for summer heat relief and were set to begin intermittent sprinkling when air temperatures in the facility reached 80°F.

Corn-soybean meal diets in meal form were formulated to contain 1.1, 1.0, .9, .8, and .7% lysine and were changed during the week average pig weight in individual pens achieved target weights of 100, 150, 200, and 250 lb, respectively.

Results and Discussion

On day 29 of the experiment, there was a linear decrease (P<.075) in pig weight and average daily gain (ADG) with increasing space (Table 1). By the 99-day weigh period, there were significant quadratic responses for pig weight, ADG, and average daily feed intake (ADFI) with the pigs given the intermediate space allocation of 9 ft^2/pig having the best performance and those given 11 ft^2/pig having the poorest performance.

The week all pigs in the facility averaged 242 lb (day 106 of the experiment), erysipelas was diagnosed. Pigs were treated under veterinary supervision with penicillin and *Erysipelothrix rhusipathiae* bacterin. No deaths occurred and all pigs appeared to recover within one week.

Overall, there was a significant quadratic effect of space allocation on ADG with the pigs given 7, 9, and 11 ft^2 growing at 1.85, 1.89, and 1.82 lb/d, respectively. No effect of space allocation on overall ADFI was detected. Feed/gain ratios worsened (P<.075) with increasing space allocations. There was no effect of space allocation on carcass backfat depth or rate of lean gain.

Uniformity of gain within pens of 12 pigs was estimated by calculating the coefficient of variation (CV) of individual pig weights within a pen when the first pig was removed at 300 lb or greater. A significant quadratic response was observed, with the least variation (CV = 6.9) in pens that provided 9 ft^2/pig while the most variation (CV = 8.2) was noted in pens that provided 7 ft^2/pig.

In this experiment, the highest ADG occurred when pigs were given 9 ft^2, while the best feed efficiency occurred at 7 ft^2. The worst pig performance (ADG and feed conversion efficiency) occurred when pigs were given the most space (11 ft^2/pig). These results suggest that barrows finished to weights approaching 300 lb require no more than 9 ft^2/pig to maximize ADG and possibly less to maximize feed conversion efficiency or gain per ft^2 of pen space.

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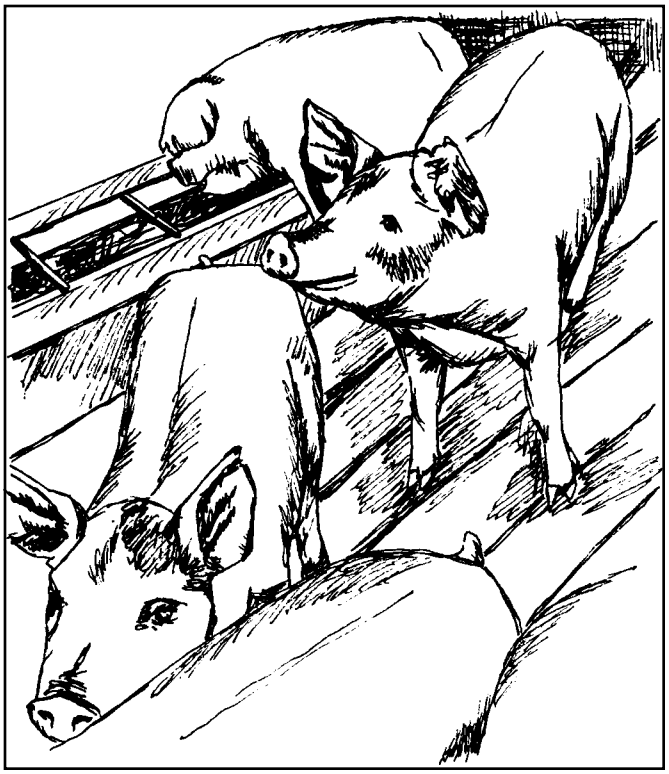

Explanation of Statistics Used in This Report

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

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

analysis is P < .01. Now the chance that random sampling of pigs caused observed treatment differences is less than 1 in 100. Evidence for real treatment differences is very strong.

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

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

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