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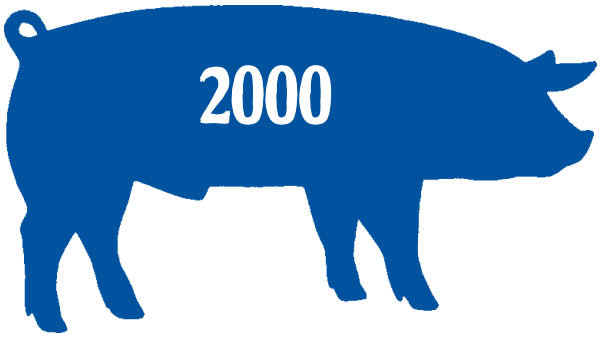
University of Nebraska Cooperative Extension EC 00-219-A



NEBRASKA SWINE REPORT

- Reproduction
- Genetics
- Health
- Nutrition
- Economics
- Housing

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

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

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

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Issued January 2000, 4,500

Swine Report Acknowledgments for 2000

Alltech Inc., Nicholasville, KY
Alpharma, Inc., Ft. Lee, NJ
BASF Corp. Mt. Olive, NJ
BioKyowa/Nutri-Quest, Inc., Chesterfield, MO
Cooperative Extension Division, University of Nebraska, Lincoln
Cotswold USA, Alden, IA
Danbred USA, Inc., Dorchester, NE
DeKalb Swine Breeders, Inc., DeKalb, IL
Heartland Pork Enterprises, Inc., Alden, IA
McGill University Health Center, Montreal, Quebec
Minitube of America, Verona, WI
Nebraska Agricultural Research Division, University of Nebraska
National Pork Producers Council, Des Moines, IA
Nebraska SPF Accrediting Agency, Lincoln, NE
Nebraska Pork Producers Association, Lincoln, NE
Pig Improvement Company, Inc., Franklin, KY
SiouxPreme Packing Co., Sioux Center, IA
U.S. Poultry and Egg Association, Tucker, GA
U.S. Meat Animal Research Center, Clay Center, NE
Waldo Farms, Inc., DeWitt, NE

The 2000 Nebraska Swine Report was compiled by Rodger Johnson, Professor, Department of Animal Science.

2000 Nebraska Swine Report

Editor: Daniel Moser
Typesetting & Design: Anne Moore

Cover Photo:

This edition of the University of Nebraska-Lincoln's annual Swine Report is dedicated to Dr. Dwane R. Zimmerman, who passed away in 1999 after giving 40 years of service to the Animal Science Department.

Dr. Zimmerman was a longtime contributor to swine research, including studying how to stimulate puberty in gilts and the detection of estrous in cyclic females. He made several important findings in both areas.

Dr. Zimmerman was more than a talented researcher. He also was a gifted teacher, having received the AMOCO Distinguished Teaching Award in Biological Sciences in 1979 and the Gamma Sigma Delta Teaching Award in 1978. As a teacher, Dr. Zimmerman was best known for his course Physiology and Management of Reproduction. All the exams he gave for the course were oral. While students often feared the experience of standing before their professor to be tested, they learned much from the immediate feedback and interaction.

Truly, Dr. Zimmerman represented the best traditions of University service.

Pubertal Response in Gilts to Type and Frequency of Boar Exposure and as Influenced by Genetic Line and Age at Initiation of Boar Contact

Dwane R. Zimmerman
Tom McGargill
Dan Cheleen[1]

Summary and Implications

The effectiveness of twice daily (2x) vs once daily (1x) boar exposure (BE) and the possible interaction of frequency of BE with type of BE (physical, PBE vs fence-line, FBE) was evaluated in two genetic lines of the Gene Pool population (AP, selected for early age at puberty and RLS, composite of genetic lines selected for ovulation rate or litter size) differing in average pubertal age and in RLS gilts at two different ages (130 and 154 d). Gilts from the RLS line (n=128) were allotted randomly, within litter, to once or twice daily BE, PBE or FBE and to initiation of BE starting at 130 d or 154 d. Gilts from the AP line (n=64) were allotted randomly to the same treatments except that BE was initiated at 130 d only in AP gilts. Two sets of three Gene Pool boars (16 months of age at start) were used to stimulate the gilts. Gilts were maintained in groups of eight per pen and were taken to the boar room for stimulation by boars. Duration of BE was standardized at 10 min per each exposure. Physical boar exposure induced a more rapid and more synchronous first estrous response than FBE, especially at the once daily frequency. Boar exposure was most effective at inducing a rapid and synchronous first estrous response when initiated in gilts nearing puberty, i.e., at 130 d in AP gilts and 154 d in RLS gilts. Added frequency of BE (2x vs 1x per d) tended to induce a more rapid pubertal response in gilts nearing onset of puberty (AP 130 d and RLS 154 d group), but not when gilts were in an earlier stage of pubertal development (RLS 130 d group). Proper timing of BE is essential to obtaining optimal pubertal response to BE. Physical boar exposure is required to achieve optimal pubertal responses with once daily BE but PBE and FBE produce comparable pubertal responses when provided twice daily.

Introduction

Frequency of boar exposure (BE) affects synchrony of pubertal estrus but the effect depends on gilts' age at initiation of BE. Earlier studies at the University of Nebraska determined that gilts provided once-daily physical boar exposure (PBE) starting at 160 d of age showed a more rapid and more synchronous first estrous response than gilts provided alternate day BE. No difference was observed between once-daily and alternate-day PBE when boar contact was initiated at 135 d of age. Australian researchers reported recently that PBE is more effective than fence-line boar exposure (FBE) and that providing PBE two or three times per day induced a more rapid pubertal response than once-daily PBE. Nebraska studies also showed that PBE was more effective than fence-line BE and twice-daily BE tended to be more effective than once-daily BE for stimulating earlier puberty when BE was initiated at 160 days. There was a trend for an interaction between type and frequency of BE but the interaction was not statistically significant. The present study evaluated the possible interaction of type and frequency of BE when initiated at two different ages and in two genetic lines of the Gene Pool population (AP, selected for early age at puberty and RLS, composite of lines selected for high ovulation rate or high litter size) that differ in average age at puberty (2-3 wk difference).

Materials and Methods

Gilts from the RLS line (n=128) were allotted randomly within litter to a replicated experiment with a 2x2x2 factorial design involving initiation of BE at two ages (130 or 154 days), two types of BE (PBE or FBE with mature 16-mo Gene Pool boars) and two frequencies of BE (2x, twice daily or 1x, once daily for 10 min per each BE). Gilts from the AP line (n=64) were assigned to the 130-day age group only because typically about half of AP gilts initiate estrous cycles on their own by

(Continued on next page)

154 days of age. Gilts were maintained in groups of eight in 6 foot x 16 foot pens during development and were taken to the boar room to receive PBE or FBE. FBE gilts were provided contact with three mature boars through a 16 foot pen divider composed of open vertical bars with 4 inch spacings. PBE gilts received physical contact with a single mature boar obtained from an adjacent pen of boars. Boars were rotated daily so that all gilts received contact with a different group or different boar on consecutive days. Estrous symptoms were observed and recorded at the AM check when all gilts were exposed to boars. Gilts were bled for progesterone determinations 7 to 10 days before and at the start of treatment to verify prepubertal status. Three AP gilts had elevated progesterone before treatment and were deleted from the study.

Results and Discussion

Pubertal responses of AP vs RLS gilts to BE at 130 days

AP gilts, as expected, showed a more rapid and more synchronous first estrous response to BE at 130 d than RLS gilts (interval to first estrus, 12.4 vs 35.2 d, P<0.01, Table 1). Overall, 69% of AP gilts and 9.4% of RLS gilts expressed estrus during the first two weeks of BE. AP gilts reached a 90% cyclic rate by the end of the fourth week of BE (91.8%) whereas RLS gilts required nine weeks to reach a comparable cyclic rate (90.3%, Figures 1 and 2). Type of BE, but not frequency of BE, affected the interval to estrus when BE was initiated at 130 d. However, there was a trend (P<0.08) for an interaction between type and frequency of BE (Table 1). PBE induced earlier expression of first estrus than FBE when BE was provided once daily (PBE, 18.8 vs FBE, 29.6 d, P<0.01), but there was no difference between PBE and FBE when BE was provided twice-daily (PBE, 23.1 vs FBE, 23.7 d, P>0.1).

Because of the more rapid response to BE, AP gilts also reached puberty at a younger age (145.5 vs 168.0d, P<0.01) than RLS gilts (Table 2). There was

Table 1. Interval to first estrus (average ± SE, days) as affected by genetic line and type and frequency of boar exposure (BE) initiated at 130 days.

Line[a]	Age at BE, d	Type of BE[b]	Frequency of BE 1x/d	Frequency of BE 2x/d	Combined
AP	130	FBE	16.8±4.1	9.7±4.4	
		PBE	12.9±4.1	10.1±4.4	
		Combined	14.8	9.9	12.4[c]
RLS	130	FBE	42.4±4.1	37.6±4.1	
		PBE	24.6±4.1	36.2±4.1	
		Combined	33.5	36.9	35.2
Overall		FBE	29.6±2.9	23.7±3.0	26.6[d]
		PBE	18.8±2.9	23.1±3.0	20.9
		Combined	24.2	23.4	

[a]AP and RLS are early age at puberty and ovulation rate-litter size select lines from the Gene Pool population.
[b]FBE and PBE = Fence-line and physical boar exposure, respectively.
[c]AP vs RLS, P<0.01.
[d]PBE vs FBE, P<0.05.

Table 2. Age at puberty (average ± SE, days) as affected by genetic line and type and frequency of boar exposure (BE) initiated at 130 days.

Line[a]	Age at BE, d	Type of BE[b]	Frequency of BE 1x/d	Frequency of BE 2x/d	Combined
AP	130	FBE	150.2±4.1	143.0±4.2	
		PBE	146.1±4.1	142.9±4.3	
		Combined	148.1	142.9	145.5[c]
RLS	130	FBE	175.6±4.1	170.6±4.1	
		PBE	157.2±4.1	168.5±4.1	
		Combined	166.4	169.6	168.0
Overall		FBE	162.9±2.9	156.8±2.9	159.9[d]
		PBE	151.6±2.9	155.7±3.0	153.7
		Combined	157.3	156.2	

[a]AP and RLS are early age at puberty and ovulation rate-litter size select lines from the Gene Pool population.
[b]FBE and PBE = Fence-line and physical boar exposure, respectively.
[c]AP vs RLS, P<0.01.
[d]PBE vs FBE, P<0.05.

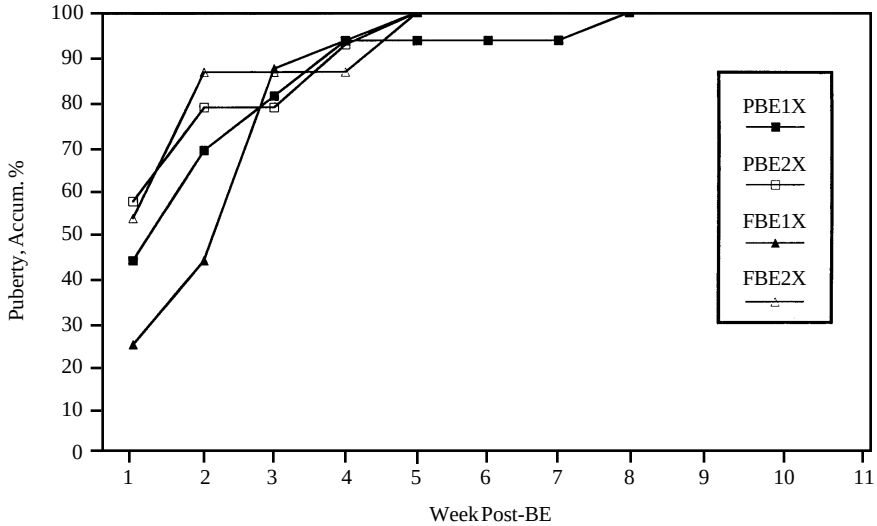

Figure 1. Accumulative pubertal response (%) of AP gilts to boar exposure (BE) by weekly intervals from initial BE at 130 days. FBE, fence-line boar exposure; PBE, physical boar exposure; 1x, once daily; 2x, twice daily.

Table 3. Interval to first estrus (average ± SE, days) in RLS gilts as affected by age of gilts and type and frequency of boar exposure (BE).

Age BE, d	Type of BE[b]	Frequency of BE 1x/d	2x/d	Combined
130	FBE	42.4±4.4	37.6±4.4	
	PBE	24.6±4.4	36.2±4.4	
	Combined	33.5	36.9	35.2
154	FBE	25.5±4.4	18.2±4.4	
	PBE	24.2±4.4	19.1±4.4	
	Combined	24.8	18.6	21.8
Overall	FBE	33.9±3.1	27.9±3.1	30.9[c]
	PBE	24.4±3.1	27.6±3.1	26.0
	Combined	29.2	27.8	

[a]FBE and PBE = Fence-line and physical boar exposure, respectively.
[b]Age, P<0.01.
[c]PBE vs FBE, P<0.11.

Table 4. Age at puberty (average ± SE, days) in RLS gilts as affected by age of gilts and type and frequency of boar exposure (BE).

Age BE, d	Type of BE[b]	Frequency of BE 1x/d	2x/d	Combined
130	FBE	175.6±4.4	170.6±4.4	
	PBE	157.2±4.4	168.5±4.4	
	Combined	166.4	169.6	168.0[b]
154	FBE	179.5±4.4	172.1±4.4	
	PBE	177.6±4.4	172.3±4.4	
	Combined	178.6	172.2	175.4
Overall	FBE	177.6±3.1	171.3±3.1	174.5[c]
	PBE	167.4±3.1	170.4±3.1	168.9
	Combined	172.5	170.9	

[a]FBE and PBE = Fence-line and physical boar exposure, respectively.
[b]130 vs 154, P<0.01.
[c]PBE vs FBE, P<0.08.

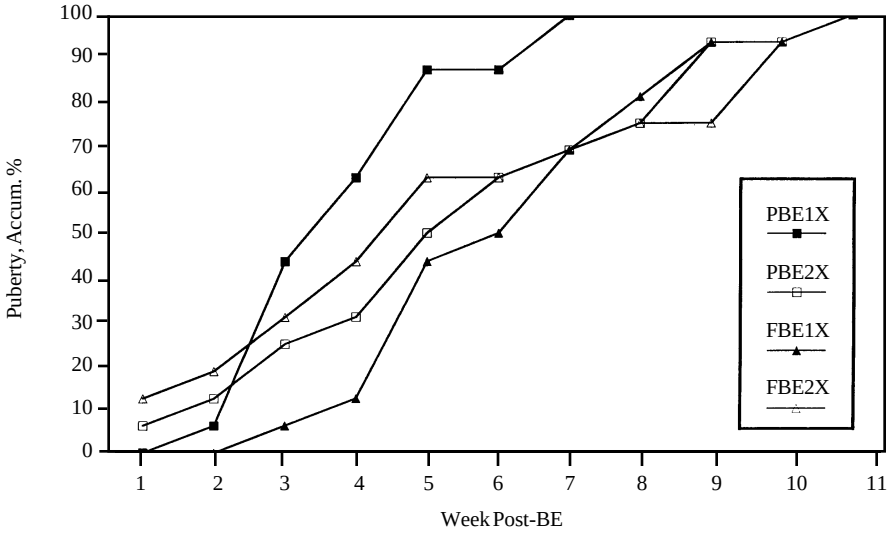

Figure 2. Accumulative pubertal response (%) of RLS gilts to boar exposure (BE) by weekly intervals from initial BE at 130 days. FBE, fence-line boar exposure; PBE, physical boar exposure; 1x, once daily; 2x, twice daily.

also a trend for an interaction between type and frequency of BE (P<0.08). PBE gilts reached puberty 11.3 d earlier than FBE gilts when gilts were provided once daily contact with boars (151.6 vs 162.9 d, P<0.01) but PBE and FBE gilts showed comparable ages at puberty when provided twice-daily BE (PBE, 155.7 vs FBE, 156.8 d, P>0.1).

Pubertal responses to BE at 130 vs 154 days in RLS gilts

RLS gilts first exposed to boars at 130 days reached puberty earlier than RLS gilts first exposed to boars at 154 d of age (168 vs 175.4 d, P<0.01, Table 4) but the interval to puberty after initiation of BE was substantially shorter in the 154-d gilts (21.8 vs 35.2 d, P<0.01, Table 3). RLS gilts first exposed to boars at 154 d also showed greater heat grouping (43.8% vs 9.4% expressed estrus within first two weeks) and achieved a 90% cycling rate sooner (92.2% in 8 wk vs 90.6% in 9 wk) than RLS gilts that received BE at 130 d (Figures 2 and 3). Overall, PBE tended to be more effective than FBE (P<0.11), but the effect on age at puberty was significant only when BE was provided once daily and initiated at 130 d of age (Table 4). Twice daily BE tended to induce a more rapid pubertal response than once daily BE in gilts nearing onset of puberty (RLS 154 d, 18.7 vs 24.8 d, P<0.05, Table 3), but not when gilts were stimulated earlier in pubertal development (RLS 130 d, 36.9 vs 33.5 d, P>0.1, Table 3).

Results of the present experiment confirmed previous findings at UNL regarding the timing of boar exposure and expected pubertal response. Initiating BE at an early stage of pubertal development (e.g., at 130 d in RLS gilts in the present study) induces earlier average age at puberty as long as boar exposure is not initiated too far ahead of the average pubertal age of the genetic group being stimulated. Previous findings at UNL revealed that Gene Pool gilts exposed to boars at 100 d (~55 d before mean pubertal age) were delayed achieving puberty

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compared to gilts provided BE starting at 125 d of age (~30 d before mean pubertal age). British researchers reported similar findings with Large White gilts. But exposing gilts to boars in early stages of pubertal development results in a delayed response to BE and induces little, if any, synchrony of pubertal estrus compared to gilts that are in more advanced stages of pubertal development when first exposed to boars (e.g., at 130 d in AP gilts and 154 d in RLS gilts in the present study). AP 130 and RLS 154 gilts first were exposed to boars about two weeks before the average pubertal age of each genetic group (145.5 and 168 d mean pubertal age of AP 130 d and RLS 130 d groups, respectively). The more rapid and more synchronous first estrous response with more optimum timing of boar exposure can be achieved with little delay in average age at puberty. RLS gilts that received BE at 154 d expressed first estrus only 7 d later than RLS gilts exposed to boars at 130 d. Synchrony of first estrus is desirable when programming replacement gilts into the gilt pool for later breeding. And the time and labor required to stimulate gilts may be reduced, depending on the method used to stimulate developing gilts with boars.

The hypothesis that type and frequency of boar exposure interact in inducing a rapid and synchronous first estrous response in gilts was confirmed in this study. PBE was more effective than FBE when provided once daily and initiated at 130 d but produced comparable responses to FBE when provided twice-daily or when initiated at 154 d (RLS gilts). This occurred, in part, because gilts nearing puberty at the time of initiation of BE (AP 130 and RLS 154 groups) responded more rapidly to twice-daily BE than to once daily BE. In other words, increasing frequency from once-daily to twice-daily BE improved the pubertal response to FBE and negated the difference observed between PBE and FBE with once-daily BE.

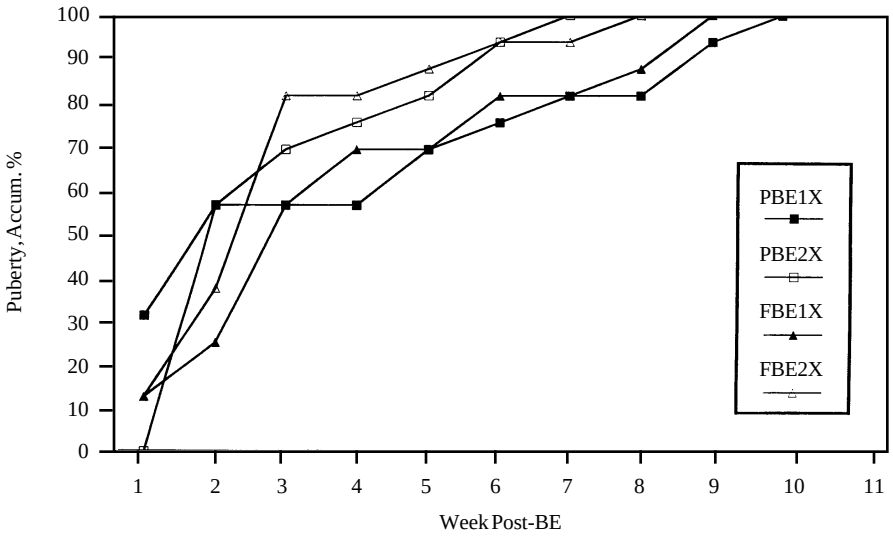

Figure 3. Accumulative pubertal response (%) of RLS gilts to boar exposure (BE) by weekly interval from initial BE at 154 days. FBE, fence-line boar exposure; PBE, physical boar exposure; 1x, once daily; 2x, twice daily.

Previous research findings of Australian and UNL researchers (1998 Swine Report) demonstrated that PBE is more effective than FBE at inducing earlier puberty in gilts. The Nebraska study also used RLS gilts and observed that the interval to first estrus was 9.5 d shorter in PBE than FBE gilts first exposed to boars at 160 d. Twice-daily BE also tended to be more effective than once-daily BE but most of the advantage was achieved in combination with FBE rather than PBE.

Although the interactions between type and frequency of BE were not statistically significant (P>0.05) in either study, the trend for an interaction in the present study and the consistency of responses in the two studies provides evidence that twice-daily FBE is required to produce comparable responses to once-daily PBE. Frequency of BE is of lesser concern for PBE gilts.

Conclusion

Physical BE is required to achieve the optimal intervals and synchrony of first estrus in gilts. Increased frequency of BE from once to twice-daily offers little advantage when using PBE but is definitely more efficacious when using FBE. Initiation of BE must be timed appropriately relative to average pubertal age of the genetic group being stimulated, i.e., one to two weeks before most gilts in the group are destined to reach puberty, in order to achieve optimal intervals and synchrony of puberty estrus following boar exposure.

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[1]Dwane R. Zimmerman was professor of animal science. Tom McGargill and Dan Cheleen hold agricultural research technician II positions.

Candidate Reproductive Genes Do Not Explain Responses in Lines Selected for Ovulation Rate and Litter Size

Regina Linville
Rodger Johnson
Daniel Pomp[1]

Summary and Implications

Molecular technologies have developed rapidly and provide methods to select directly for genes controlling economic traits. The swine genetic linkage map is the most highly developed of all livestock species. Positions on the chromosomes of several genes are known. Some of these genes have been shown to have direct effects on economic traits. Selection lines that differ from the control line by as much as 50% in ovulation rate and litter size exist at Nebraska. This experiment evaluated whether six specific genes that produce important proteins in reproductive processes explained responses in ovulation rate and litter size in two of these lines. The genes studied were follicle stimulating hormone (FSHβ), prostaglandin endoperoxide-synthase 2 (PTGS2), estrogen receptor (ESR), prolactin receptor (PRLR), retinol binding protein (RBP4), and epidermal growth factor (EGF). Distributions of genotypes for five of the six genes differed among lines. However, line differences in gene frequencies were not greater than what might have occurred due to random genetic drift associated with inbreeding. Furthermore, estimates of the effects of the genes on ovulation rate and litter size were not significant. Therefore, these genes did not have large effects on litter size in this population and did not explain the observed responses to selection. Either other genes with major effects were involved, or there are a large number of genes each with small effects that control expression of the traits. Additional work is being done to determine whether other genes were involved. However, until those genes are identified, swine breeders must rely on traditional breeding methods to improve reproductive traits.

Background

Ovulation rate sets the upper limit to litter size. It is heritable and responds to selection. However, in lines selected for increased ovulation rate, only 25% of each additional ova was realized as a pig at birth. Ovulation rate and number of embryos at 50 days of gestation are moderately correlated, but fetal losses after 50 days increased in the high ovulation line.

Uterine capacity is defined as the number of fetuses that a uterus can carry to term when ovulation rate is not limiting. Insufficient uterine capacity exists when number of potentially viable embryos, determined largely by ovulation rate, exceeds the number of fetuses the uterus can carry to parturition. The excess fetuses either die and are reabsorbed by the uterus or expelled as a mummified pig at birth, or survive to parturition but have very small birth weights and low survival rates.

At Nebraska, a selection strategy was used to select both for increased ovulation rate and increased uterine capacity. First gilts with increased ovulation rate were selected. Then, selection for increased litter size in females with high ovulation rate was practiced. The theory is that females first selected for ovulation rate have more potentially viable embryos than their uterus can carry to parturition. The number of pigs at birth is then a measure of the female's uterine capacity. Selection was practiced in two lines. One of these lines had increased ovulation rate and litter size due to previous selection; the other started from an unselected base. A randomly selected control line was maintained to monitor response in the selection lines.

The selection procedure used laparotomy to count corpora lutea as a measure of ovulation rate. This procedure still is not practical in most genetic selection programs. This surgical procedure could be avoided by selecting directly for genes controlling expression of the traits. Molecular technologies are developing rapidly and offer promise of being able to select directly for genes controlling economic traits. The swine genetic linkage map is the most highly developed of all livestock species. Positions on the chromosomes of several genes are known. Some of these genes have been shown to have direct effects on economic traits. Most of the genes mapped and with known effects control variation in growth and fatness traits. An example is the ryanodine receptor which

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reduces fatness, but also causes the PSS condition. A few genes with effects on reproductive traits have been identified. Certain other genes are prime candidates to have effects on reproduction because they produce products known to have physiological functions in the reproductive process.

Selection directly for genes controlling ovulation rate and litter size would enhance responses. Selection could be applied in both sexes instead of only in females. Selection accuracy would be increased. And surgical procedures to measure ovulation rate would not be necessary. The purpose of the experiment reported herein was to determine whether certain candidate genes explain a significant portion of the responses in the Nebraska lines selected for increased ovulation rate and uterine capacity.

The Lines

The pigs were from two selection lines designated IOL and COL and Line C, a randomly selected control. These lines originated from the Index selection and Control lines developed at the University of Nebraska. The Index and Control lines have a common base of the Large White and Landrace breeds. Beginning in 1981, the Index line was selected eight generations for increased ovulation rate and increased embryonic survival to 50 days of gestation. The control line was selected randomly. At generation 8, three new lines were formed, one from the Index line and two from the Control line. The line originating from the Index line is designated Line IOL, the lines originating from the Control line are designated as COL and C. Eight generations of two-stage selection for increased ovulation rate and increased litter size in lines IOL and COL were practiced. In the first stage, all gilts born to the 50% of the sows with the greatest litter size at birth were selected. Laparotomy about 10 days after their second estrous period (first estrus following their pubertal estrus) was performed to count number of corpora lutea. Stage two selection included the 50% of these gilts with the greatest ovulation rate. Each line had approximately 45 litters by 15 sires each generation. Replacement boars were from the 15 largest litters. Replacements in Line C were selected randomly.

DNA Analyses

Ear tissue was collected from pigs in generations 7 and 8. Only selected gilts and boars of generation 8 were sampled. Tissue was collected from all generation-7 gilts in which laparotomy was performed. Genotypes of 190 animals of generation 7 and 334 of generation 8 were determined. DNA was extracted from the tissue and analyzed to determine the genotype of each pig for six genes. These genes were selected because of their known physiological function in reproductive processes or because they had been found in other studies to affect litter size.

Genes

Estrogen Receptor.

At least eight estrogens are secreted by the ovary, with estradiol being the primary one. These steroid hormones have a wide range of activities. They are important behavioral hormones and are involved in uterine growth and in maternal recognition of pregnancy. Estrogen receptor is a nuclear protein that binds steroid hormones and allows them to penetrate the plasma membrane to perform their function. Pigs with different genotypes for the estrogen receptor gene (ESR) were reported to differ in litter size. In some populations, females homozygous for the B allele had about .4 pigs more per litter than those homozygous for the A allele (Short et al., 1997; J. Anim Sci. 75:3138).

Prolactin Receptor.

Prolactin is important in mammary growth and in milk synthesis. It also affects the growth and function of ovaries and testes and the action of gonadotrophic hormones. It is necessary for maintenance of corpora lutea and affects production of the hormones progesterone and relaxin. Prolactin receptors (PRLR) are proteins that bind with prolactin in the corpora lutea. Females of Landrace, Large White, and Chinese Meishan breeds with the AA genotype had .66 pigs more than those with the BB genotype (Vincent et al., 1998; Proc. 6th World Cong. Applied to Livest. Prod. 15:18).

Follicle stimulating hormone β.

Follicle stimulating hormone is a protein produced by the anterior pituitary. It has two distinct subunits, α and β, coded for by two different genes. FSH acts predominantly on the cells of the follicles within the ovary. It is critical in the growth and selection of those that will mature and subsequently ovulate. FSHβ was chosen to study because in a report from the China Agriculture University in Beijing (Li et al., 1998; Proc. 6th World Cong. Applied to Livest. Prod. 15:183) it was reported to be a major gene affecting litter size in crosses of Chinese breeds with Duroc and Yorkshire.

Epidermal Growth Factor.

Epidermal growth factor (EGF) has many functions in adults, including proliferation and differentiation of the epidermis and in wound healing. It also is transcribed in early embryonic development by the conceptus and by the uterus of the sow. In embryos and neonates it stimulates pulmonary epithelia to grow and mature and it stimulates proliferation of skin epithelia. It was chosen as a candidate gene because Landrace, Large White, Pietrain, and Chinese breeds, which differ in litter size, also had quite different EGF genotypic frequencies (Mendez et al., 1999; J. Anim Sci. 77:492), although no direct relationship with litter size was reported.

Retinol Binding Protein 4.

Retinol binding protein 4 (RBP4) is secreted by the conceptus into the uterine lumen between 10 and 15 days

of gestation. It is a major secretory product during this period. It is thought to function in the transport of retinoids to the conceptus. This period is a dynamic time for mother and conceptus during which several physiological and biochemical interactions must occur for proper fetal development. This major protein enhances gene expression of a particular growth factor (Transforming Growth Factor β) via retinoic acid receptors. RBP4 was reported to have an additive effect on litter size of .52 ± .30 pigs in the French Hyperprolific Large White breed (Messer et al., 1996; Mammalian . Genome 7:396).

Prostaglandin-Endoperoxide Synthase 2.

Prostaglandin-Endoperoxide Synthase 2 (PTGS2) is the rate limiting enzyme in the formation of prostaglandins. Although it has not been shown to directly affect litter size, it was chosen as a candidate gene because mice homozygous for a "knockout" gene (a procedure to suppress expression of the gene) were infertile and had few ovulations. The uterus of mutant mice also did not support growth of normal embryos transplanted into them (Lim et al, 1997; Cell 91:197).

Statistical Analyses

Gene and genotypic frequencies within each line were calculated. If a gene affects ovulation rate or litter size, then we expect both genotypic and gene frequencies to differ among lines, with the frequency of the favorable allele and the favorable genotype being greater in the selection lines than in the control line. Chi-square analyses were used to test whether genotypic distributions among lines were different. When lines are separated by several generations, both selection and the random changes associated with inbreeding can cause them to have different genotypic and gene frequencies. To determine whether changes in gene frequencies were greater than what might have occurred by chance, variances of gene frequency changes were adjusted for genetic drift before gene frequency differences among lines were tested statistically.

Favorable alleles of each gene were defined as the ones that had been increased in frequency in the selection lines compared to the control line. The effect of this gene on each trait was estimated by analyzing the data with analysis of variance procedures, calculating the average phenotypic value for each genotypic class and making contrasts among these means to estimate additive and dominance effects of the genes. The additive effect, (a) was calculated as the mean phenotype of females homozygous for the favorable allele minus the mean for those homozygous for the unfavorable allele. The dominance effect, (d) was calculated as the mean of animals with heterozygous genotypes minus the average of those with the two homozygous genotypes. For example, for favorable allele A, a = AA - BB, and d = AB - .5(AA + BB). Estimates of a and d were tested to determine whether they differed from zero. Values different from zero are interpreted to mean that the gene affected the trait being analyzed. All tests of a and d effects were performed with procedures that corrected for differences in genetic value due to inbreeding and to effects of other genes not included in the model.

Table 1. Phenotypic means[a] for generations 7 and 8.

Line	N_{OR}	N_{FF}	OR	FF	NBA	SB	M
			Generation 7				
IOL	90	43	19.0	13.4	11.1	2.3	.5
COL	90	45	15.1	11.8	10.8	1.1	.5
C	51	35	12.9	9.6	9.0	.6	.2
			Generation 8				
IOL		42		12.4	10.9	1.8	1.2
COL		40		10.2	9.9	.6	1.2
C		32		7.4	7.2	.6	1.0

[a]OR = ovulation rate, FF = number of fully formed pigs, NBA = number born alive, SB = number of stillborn pigs, and M = number of mummified pigs per litter. N_{OR} = number of ovulation rate records, and N_{FF} = number of litter size records.

Results

Phenotypic means of the traits studied are in Table 1. Line IOL and C are separated by 16 generations of selection and Lines COL and C are separated by 8 generations. Lines differ significantly for all traits studied. The genetic differences between Lines IOL and C at generation 8 were estimated to be 6.1 ova and 4.7 fully formed pigs at birth; whereas, Lines COL and C differ by 2.2 ova and 2.9 fully formed pigs. Total responses between Lines IOL and C are approximately 50% in both number of ova and fully formed pigs per litter. Differences in number born live are less because increased numbers of stillborn and mummified pigs accompanied the genetic increases in ovulation rate and fully formed pigs. However, these differences provide substantial genetic variation to determine whether specific genes were being selected for.

Distributions of genotypes of FSHβ, PTGS2, ESR, PRLR, and RPB4 differed significantly among lines (Table 2). For all but ESR genotypes, one genotype was most frequent in the selection lines compared to the control, as if selection had acted on these genes. For example, most animals had FSHβ genotype BB in both Lines IOL and COL, whereas the frequency of that genotype was less in Line C. Similar results occurred for PTGS2 and PRLR. There was a high frequency of ESR AA genotype in all lines and the distributions of ESR genotypes are such that the Chi-square statistic is biased. Chi-square tests are biased upward when fewer than five observations occur in some cells; therefore we cannot infer that distributions of ESR genotypes differ among lines.

The fact that lines differ in genotypic distributions does not mean that

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the difference was caused by selection acting on the genes. Other events such as nonrandom mating of parents, different distributions of genotypes in selected parents and random gene frequency changes over generations due to inbreeding along with selection can cause different genotypic frequencies.

Selection operates directly to increase frequencies of genes controlling the selected trait. But random drift associated with inbreeding also causes closed lines to have different gene frequencies. Gene frequencies of each line were calculated and contrasts of frequencies in selection and control lines were made (Table 3). Inbreeding in the lines was .14 in Lines C and COL and .19 in Line IOL. With this amount of inbreeding, considerable random drift in gene frequency might have occurred since lines were closed. To determine whether the gene frequency differences between selection and control lines were greater than what might have occurred by chance, standard errors of changes in gene frequency adjusted for inbreeding were calculated. When differences among lines were tested without adjusting standard errors for inbreeding, several of the differences were significant. However, after adjusting for inbreeding none of the changes in gene frequency were significantly different from zero. Therefore, genotypic distributions of the genes were different because the lines had different gene frequencies, but these differences likely were not caused by selection.

The distributions of gene frequencies in Table 3 have a pattern consistent with what would have occurred if the genes controlled expression of the traits selected for in Lines IOL and COL. For example, Lines IOL and C are separated by 16 generations of selection and Lines COL and C are separated by 8 generations of selection. Compared to Line C, the frequency of the B allele of FSHβ increased by .15 in COL and .35 in IOL, as if the change was directly related to the selection applied. A similar pattern occurred for PTGS2 and PRLR. To further evaluate effects of these genes, the average performance of animals with each genotype was calculated and used to calculate a and d effects. Estimates of these effects along with their standard errors are in Table 4. No estimates differed significantly from zero. Furthermore, in some cases the sign on the estimate is

Table 2. Distributions of genotypes and Chi-Square (χ^2) statistics.

Item	IOL			COL			C			
	AA	AB	BB	AA	AB	BB	AA	AB	BB	χ^2
FSHβ	0	12	176	8	73	115	16	70	50	124.7**
PTGS2	181	8	0	162	33	2	94	36	7	47.2**
ESR	166	22	1	198	0	0	136	0	0	42.5**
PRLR	4	64	121	23	97	78	35	73	29	79.6**
RBP4	8	46	13	15	35	19	12	21	21	12.3*
EGF	0	8	58	0	13	55	0	11	45	2.7

*P < .05.
**P < .01.

Table 3. Frequency of each gene and contrasts of frequencies between selection lines and the control.

Gene	IOL	COL	C	IOL-C	SE	COL-C	SE
FSHβ, B	.97	.77	.62	.35	.20	.15	.24
PTGS2, A	.98	.90	.82	.16	.16	.08	.18
ESR, A	.94	1.00	1.00	.06	.12	0	.12
PRLR, B	.81	.64	.58	.33	.25	.16	.04
RBP4, B	.54	.53	.58	.04	.29	.05	.06
EGF, B	.94	.90	.90	.04	.06	0	.16

Table 4. Additive (a) and dominance (d) effects with an animal model.[a,b]

Candidate gene	Contrast		OR	s.e.	FF	s.e.	NBA	s.e.	Stillborn	s.e.	Mummies	s.e.
PRLR	BB-AA	a	-.287	.27	-.039	.38	-.007	.366	-.028	.184	.091	.103
		d	-.445	.32	-.229	.462	-.466	.44	.164	.219	.063	.126
PTGS2	AA-BB	a	.036	.64	.589	.833	.403	.795	.184	.399	.273	.226
		d	.448	.71	.354	.953	.076	.909	.278	.454	.741	.259
ESR	BB-AA	a	.108	1.3	1.74	1.6	.474	1.52	1.25	.761	.341	.437
		d	2.33	1.42	2.72	1.98	1.58	1.88	1.13	.933	.37	.54
FSHβ	BB-AA	a	-.04	.34	.163	.466	.12	.446	.045	.223	.246	.127
		d	-.039	.41	.979	.577	.759	.549	.222	.273	.0481	.157
RBP4	BB-AA	a	.284	.38	-.179	.457	-.526	.436	.346	.22	.026	.124
		d	.315	.49	.441	.627	.313	.595	.0936	.298	-.0479	.17

[a]EGF could not be estimated with contrasts because there was only two genotypes.
[b]Traits ovulation rate (OR), number of fully formed pigs (FF), number born alive (NBA), stillborn and mummies. Candidate genes used were follicle stimulating hormone (FSHβ), prostaglandin endoperoxide-synthase 2 (PTGS2), estrogen receptor (ESR), prolactin receptor (PRLR), retinol binding protein (RBP4), and epidermal growth factor (EGF). The additive contrast is given as the favorable genotype minus the less favorable genotype, as determined by the most frequent allele in the selection lines.

opposite of what was expected based on gene frequencies in the lines. For example, the PRLR B allele was increased in the selection lines, but it had a negative effect on both ovulation rate and number of pigs in the litter. This provides additional evidence that the genes studied did not affect the traits selected for in this experiment and that the changes in their frequency in the selection lines were due to random genetic drift.

Conclusion

Some of the genes studied had different gene frequencies in the selection lines compared to the control line. However, these differences were not greater than what might have occurred by chance due to inbreeding. Estimates of the effects of these genes on ovulation rate and litter size were not significant and in some cases signs of these effects were opposite of the changes in gene frequencies. Thus, we conclude that these genes did not contribute to the genetic changes in ovulation rate and litter size in the selection lines.

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The Effect of Oxytocin at the Time of Insemination on Reproductive Performance — A Review

Donald G. Levis[1]

Summary and Implications

Oxytocin is released from the brain of the sow at the time of mating in response to stimulation by the boar. It is assumed that it enhances sperm transport to the oviduct. Several investigators have studied whether injecting oxytocin into semen before artificial insemination improves farrowing rate and litter size. The conclusions from review of these studies are: 1) Adding 4 to 5 IU's of oxytocin to a dose of semen improves farrowing rate and litter size; 2) Use of oxytocin-treated semen is more effective in multiparous sows than gilts; 3) During the summer months, oxytocin-treated semen significantly increased farrowing rate and litter size; and 4) In most studies, the use of oxytocin at the time of insemination was profitable. Oxytocin should be added to the semen with an insulin syringe immediately before attaching the semen vessel to the insemination catheter.

Introduction

Although billions of spermatozoa are deposited in the cervix of the female pig during the process of artificial insemination, only thousands of sperm are found in the oviduct. Sperm cells are transported to the oviduct within 15 minutes to 2 hours after deposition in the cervix. To prevent them from being phagocytized (killed) by leukocytes, it is extremely important that sperm cells arrive in the oviduct as quickly as possible. Fertilization of ova occurs at the ampulla-isthmus junction of the oviduct.

Oxytocin concentration in the blood of sows increases dramatically within 2 minutes of the onset of ejaculation by a mature boar. In addition, the plasma concentration of oxytocin starts to increase when the nose of a sow is sprayed for two seconds with a synthetic boar pheromone (Sex Odor Aerosal, 5a-androst-16-en-3-one). This short-term increase of oxytocin supports the rapid sperm transport mechanisms immediately after mating. Several investigators have studied whether farrowing rate and litter size are enhanced by adding: (1) oxytocin or an oxytocin analogue to a dose of semen just before insemination, or (2) by injecting oxytocin into the muscle or vulva 2 to 5 minutes before insemination.

Toxicity of Oxytocin

Before adding oxytocin to semen, it is extremely important to know whether it has detrimental effects on spermatozoa. A study in Czechoslovakia evaluated the effect of adding various concentrations of oxytocin or an oxytocin analogue (Depotocin) on sperm motility over a duration of four hours (Table 1). When .25, .50 or 1.0 International Units (IU) of oxytocin or .50, 1.0, or 2.0 IU of Depotocin was added to 8 mL of semen, estimated motility of sperm cells was not different from the control sample after 60 minutes of storage. Detrimental effects on sperm motility occurred in samples containing .125 IU or greater of oxytocin per mL at 120 minutes after adding oxytocin. The study did

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Table 1. The influence of oxytocin and Depotocin (oxytocin analogue) on motility of spermatozoa during storage.

		Oxytocin, mL			Depotocin, mL			Control
		.05	.10	.20	.05	.10	.20	
Volume of semen, mL		8	8	8	8	8	8	8
IU of oxytocin		.25	.50	1.0	.50	1.0	2.0	0
IU of oxytocin/mL of semen		.0313	.0625	.1250	.0625	.1250	.2500	0
Number of ejaculates	Duration of time after adding oxytocin, minutes	Progressive motility of spermatozoa, %						
12	60	75 (60 to 80)[a]	74 (60 to 80)	70 (60 to 80)	73 (60 to 80)	73 (60 to 80)	72 (60 to 80)	75 (60 to 80)
12	120	64 (60 to 80)	73 (60 to 80)	59 (50 to 70)	75 (60 to 80)	71 (50 to 80)	61 (50 to 70)	74 (60 to 80)
12	180	73 (50 to 80)	70 (50 to 80)	55 (50 to 70)	73 (60 to 80)	69 (50 to 80)	56 (40 to 70)	73 (60 to 80)
12	240	74 (60 to 80)	69 (50 to 80)	48 (20 to 70)	72 (60 to 80)	67 (50 to 70)	39 (30 to 60)	71 (60 to 80)

[a]Range in estimate of sperm motility.
Reference: Biologizac a Chemizace Zivocisne Vyroby-Veterinaria 20(2):181-191, 1984.

not evaluate the effect of oxytocin in the semen on farrowing rate or litter size.

International Units of Oxytocin per Dose of Semen

A scientific study that evaluated an equally spaced range of IU's of oxytocin in semen on farrowing rate and litter size was not found. In most studies, 4, 5 or 10 IU of oxytocin per dose of semen (100 mL) were added immediately before attaching the semen vessel to the AI catheter. Table 2 has results of four such studies. In Study 1, the addition of 4 IU of oxytocin to a dose of semen immediately before insemination produced a numerically greater farrowing rate, number of pigs born live and fecundity index (FI) compared to control sows. In the three studies that used 5 IU of oxytocin, Studies 2 and 3 showed a small numeric increase in farrowing rate and FI for sows inseminated with semen containing 5 IU oxytocin compared to control sows. However, Study 4 found a 5.8 percent decrease in farrowing rate and a 14 pig decrease in FI for sows inseminated with oxytocin-treated semen compared to control sows. Although the addition of 10 IU of oxytocin to semen in Study 4 showed a small beneficial effect on average number of pigs born live per litter compared to control sows, the farrowing rate of sows inseminated with oxytocin-treated semen was reduced by 8.1 percent and the FI was reduced by 64 pigs. These studies did not partition the data to determine whether oxytocin-treated semen produced the same results in all parities.

Table 2. Influence of oxytocin-treated semen on reproductive performance.

	International Units (IU) of Oxytocin added to semen at time of insemination				Difference		
	Control (C)	4 IU	5 IU	10 IU	C - 4 IU	C - 5 IU	C - 10 IU
Study 1: Proc. 11th International Congress Anim. Reprod. & AI, Vol 3, pp 239-240, 1988.							
# Sows	35	36	—	—	-1	—	—
FR, %[a]	88.6	94.4	—	—	-5.8	—	—
# BA[b]	9.39	10.21	—	—	-.82	—	—
FI[c]	832	964	—	—	-132	—	—
Study 2: Anim. Breed. Abstracts 52(11); Abstract No. 6718, 1984.							
# Sows	211	—	176	—	—	35	—
FR, %	77.2	—	78.4	—	—	-1.2	—
# BA	9.19	—	9.23	—	—	-.04	—
FI	709	—	724	—	—	-15	—
Study 3: Anim. Breed. Abstracts 53(6); Abstract No. 3776, 1985.							
# Sows	494	—	405	—	—	89	—
FR, %	81.0	—	84.0	—	—	-3.0	—
# BA	10.4	—	10.2	—	—	.2	—
FI	842	—	857	—	—	-15	—
Study 4: Anim. Breed. Abstracts 53(12); Abstract No. 7740, 1985.							
# Sows	99	—	100	98	—	-1	1
FR, %	92.8	—	87.0	84.7	—	5.8	8.1
# BA	9.9	—	10.4	10.1	—	-.5	-.2
FI	919	—	905	855	—	14	64

[a]Farrowing rate of sows bred.
[b]Average number of piglets born live per litter.
[c]Fecundity index per 100 sows (farrowing rate x number of pigs born live).

Effect of Parity

Table 3 contains the results of oxytocin-treated semen on reproductive performance of gilts and sows. In

Table 3. The influence of oxytocin-treated semen on reproductive performance of gilts and multiparous sows.

Item	Oxytocin[a] (O)	Control (C)	Difference (C - O)
Study 1: Archiv fur Experimentelle Veterinarmedizin 31(4):561-566, 1977			
Gilts			
Number of females	315	296	-19
Farrowing rate, %	80.6*	74.3	-6.3
Total piglets/ litter	9.07	9.10	.03
Live piglets/litter	8.00	7.96	-.04
Fecundity index	645	591	-54
Multiparous			
Number of females	377	385	8
Farrowing rate, %	88.6	89.4	.8
Total piglets/ litter	11.25	11.25	0
Live piglets/litter	10.12	9.98	-.14
Fecundity index	897	892	-5
Study 2: Zivocisna Vyroba 33(9):845-850, 1988			
Gilts			
Number of females	342	606	264
Farrowing rate, %	67.8	69.6	1.8
Piglets born per litter	8.3	8.4	.1
Fecundity index	563	585	22
Multiparous			
Number of females	1418	587	-831
Farrowing rate, %	79.8*	75.6	-4.2
Piglets born per litter	9.9*	9.7	-.2
Fecundity index	790	733	-57

[a]5 IU of oxytocin added to semen at time of insemination.
*Means are significantly different (P < .05) between treatments.

Study 1, farrowing rate was significantly (P < .05) increased in gilts inseminated with oxytocin-treated semen compared to control gilts. However, farrowing rate of multiparous sows was not different between sows inseminated with oxytocin-treated semen and control sows. In Study 2, the addition of 5 IU of oxytocin to the semen just before inseminating gilts did not improve their farrowing rate or number of piglets. However, farrowing rate and number of piglets born per litter were significantly (P < .05) improved in multiparous sows inseminated with oxytocin-treated semen compared to control sows.

A Czechoslovakian study evaluated the influence of adding 5 IU of oxytocin in the semen immediately before insemination on farrowing rate and litter size by parity (Table 4). The addition of oxytocin to semen inseminated into gilts did not improve farrowing rate, total number of pigs born per litter, number of pigs born live per litter, or FI. Except for 3rd parity sows, the addition of oxytocin to semen had

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Table 4. Influence of oxytocin-treated semen on farrowing rate and litter size by parity.

	Farrowing rate, %			Average number of piglets born per litter						Fecundity index[d]	
				Total born			Live born				
Parity	Oxytocin[a] (O)	Control (C)	C - O	Oxytocin	Control	C - O	Oxytocin	Control	C - O	Oxytocin	Control
1 (Gilts)	68.78 (157)[b]	69.52 (105)[b]	.74	7.63 (108)[c]	7.63 (73)[c]	0	7.08	7.20	.12	487	501
2	76.19 (105)	75.90 (83)	-.29	8.72 (80)	8.71 (63)	-.01	8.13	8.11	-.02	619	616
3	77.08 (96)	77.21 (79)	.13	8.77 (74)	8.62 (61)	-.15	8.37	7.98	-.39	645	616
4	75.49 (102)	72.88 (59)	-2.6	9.09 (77)	8.83 (43)	-.26	8.38	8.13	-.25	633	593
5	81.52 (92)	80.85 (47)	-.67	9.74 (75)	9.47 (38)	-.27	9.08	8.65	-.43	740	699
6	86.11 (72)	75.00 (40)	-11.11	10.27 (62.)	9.53 (30)	-.74	9.53	8.33	-1.2	821	625
7+	84.84 (99)	76.00 (30)	-8.84	10.52 (84)	10.56 (23)	.04	9.42	8.82	-.60	799	670
2 to 7+	79.85 (566)	76.33 (338)	-3.52	9.50 (452)	9.08 (258)	-.42	8.79	8.25	-.54	702	630
Total	77.45 (723)	74.71 (443)	-2.74	9.13 (560)	8.76 (331)	-.37	8.45	8.02	-.43	654	599

[a]5 IU of oxytocin sofa was added to the extended semen at time of insemination.
[b]Number of females inseminated.
[c]Number of females farrowed.
[d]Number of pigs per 100 sows (farrowing rate x litter size born live).
Reference: Veterinarstvi 28(9):395-397, 1978.

a positive effect on farrowing rate of multiparous sows. The largest effect of oxytocin on farrowing rate occurred for sows in their 6th or greater parity. The addition of 5 IU of oxytocin to semen had a positive effect on number of piglets born live per litter for sows in their 2nd or greater parity. Because of the positive effect on number of piglets born live per litter for sows inseminated with semen containing oxytocin, the FI was numerically greater for Parity 2 or greater.

In a trial involving 17,755 sows and gilts at 21 breeding stations in Germany, the addition of 4 to 5 IU of oxytocin to the semen just before insemination did not significantly increase farrowing rate or litter size (Table 5). However, when the data set was partitioned into gilts, primiparous and multiparous females, the average number of piglets born live was significantly (P < .05) greater in multiparous sows inseminated with oxytocin-treated semen compared to control sows. When the data set only included industrialized pig farms, females inseminated with oxytocin-treated semen had a small increase in farrowing rate compared to control sows (Table 6). Although gilts inseminated with oxytocin-treated semen had a .03 pig decrease in average number of piglets born per litter compared to control sows, they had an FI advantage of 14 pigs because of a 1.8 percent increase in farrowing rate. Parity 2 sows inseminated with oxytocin-treated semen had a small advantage for average number of pigs born live per litter and FI. Parity 3 and greater sows inseminated with oxytocin-treated semen had .24 more pigs born live per litter and a 28 pig advantage for FI compared to control sows.

Table 5. Effect of oxytocin-treated semen on reproductive performance of gilts, primiparous and multiparous sows.

Item	Control	Oxytocin	Control - Oxytocin
All females on the experiment			
Number of females	8721	9034	-313
Farrowing rate, %	78.1	78.2	-.1
Avg pigs born/litter	10.70 ± 3.23	10.80 ± 3.23	-.10
Avg pigs born live	10.18 ± 3.09	10.28 ± 3.08	-.10
Fecundity index	795	804	-9
Gilts			
Number of gilts	2,663	2,903	-240
Farrowing rate, %	73.8	72.5	1.3
Avg pigs born/litter	9.60 ± 3.12	9.19 ± 2.98	.41
Avg pigs born live	9.11 ± 3.04	9.07 ± 3.07	.04
Fecundity index	672	658	14
Primiparous			
Number of sows	1,819	1,831	-12
Farrowing rate, %	76.7	78.6	-1.9
Avg pigs born/litter	10.90 ± 3.2	10.80 ± 3.23	0.1
Avg pigs born live	10.37 ± 3.06	10.36 ± 3.11	.01
Fecundity index	795	814	-19
Multiparous			
Number of sows	4,239	4,300	-61
Farrowing rate, %	81.3	82.0	-.7
Avg pigs born/litter	11.30 ± 3.13	11.50 ± 3.13	-.2
Avg pigs born live	10.71 ± 2.97	10.88 ± 2.96[a]	-.17
Fecundity index	871	892	-21

[a]Sow inseminated with oxytocin in semen had a significant (P < .05) increase in number of pigs born live per litter.
Reference: Monatshefte fur Veterinarmedizin 41(23):807-810, 1986.

Table 6. Influence of oxytocin on farrowing rate and litter size by parity for industrialized pig farms in Germany.

	Farrowing rate, %			Number of piglets born live per litter (mean ± SD)			Fecundity index		
Parity	Oxytocin[a](O)	Control (C)	C - O	Oxytocin	Control	C - O	Oxytocin	Control	C - O
1	69.6 (1342)[b]	67.8 (1467)[b]	-1.8	9.14 ± 3.02	9.17 ± 3.00	.03	636	622	-14
2	75.5 (1051)	74.4 (1026)	-1.1	10.15 ± 3.21	10.07 ± 3.27	-.08	766	749	-17
3+	81.7 (2279)	80.9 (2202)	-.08	10.83 ± 2.99	10.59 ± 3.10	-.24	885	857	-28

[a]4 to 5 IU Oxytocin-Spofa added to semen at time of insemination.
[b]Number of females inseminated.
Reference: Monatshefte fur Veterinarmedizin 41(23):807-810, 1986.

Effect of Oxytocin Analogue

An analogue of oxytocin is a synthetic product that generally has a longer duration of action than natural oxytocin. A comparison between 5 IU of oxytocin and 5 IU of Depotocin (oxytocin analogue) on farrowing rate and litter size by parity is shown in Table 7. In gilts and Parity 2 females, there was no significant difference in farrowing rate between females inseminated with semen containing oxytocin or Depotocin. In Parity 3 and greater females a significant (P < .02) increase of 10.3 percentage points in farrowing rate was found for sows inseminated with oxytocin-treated semen compared to sows inseminated with Depotocin-treated semen.

The average number of piglets

Table 7. Influence of oxytocin and Depotocin (oxytocin analogue) on farrowing rate and litter size by parity.

	Farrowing rate, %			Difference (Statistical significance of χ^2)		
Parity	Oxytocin (O)[a]	Depotocin (D)[b]	Control (C)	C - O	C - D	O - D
1 (gilts)	83.93 (56)[c]	85.48 (62)	85.29 (34)	1.36 (NS)[d]	-0.19 (NS)	-1.55 (NS)
2	89.36 (47)	88.68 (53)	90.77 (65)	1.41 (NS)	2.09 (NS)	0.68 (NS)
3+	79.88 (169)	90.20 (102)	70.31 (128)	-9.57 (NS)	-19.89 (.001)	-10.32 (.02)
Total	82.35 (272)	88.48 (217)	78.41 (227)	-3.94 (NS)	-10.07 (.01)	-6.13 (.10)
Parity	Number of piglets born live per litter (mean ± SEM)			Difference (Statistical significance of F-test)		
1 (gilts)	6.83 ± .37 (46)[c]	9.00 ± .17 (49)	7.92 ± .43 (29)	1.09 (NS)[d]	-1.08 (NS)	-2.17 (.05)
2	10.00 ± .12 (42)	9.00 ± .20 (47)	9.17 ± .21 (59)	-0.83 (.05)	0.17 (.05)	1.00 (.05)
3+	9.06 ± .13 (134)	9.06 ± .17 (102)	8.19 ± .22 (90)	-0.87 (.05)	-0.87 (.10)	0.00 (NS)
Total	8.38 ± .12 (223)	9.03 ± .14 (198)	8.43 ± .15 (178)	-0.05 (NS)	-0.60 (NS)	-0.65 (NS)

[a]5 IU (1 mL) of oxytocin was added to 80 mL of semen at time of insemination.
[b]5 IU (.5 mL) of Depotocin was added to 80 mL of semen at time of insemination.
[c]Number of sows bred.
[d]Nonsignificant difference.
Reference: Biologizac a Chemizace Zivocisne Vyroby-Veterinaria 20(2):181-191, 1984.

Table 8. Influence of oxytocin and Depotocin (oxytocin analogue) on farrowing rate and litter size by parity.

	Fecundity index[a]			Difference between treatments		
Parity	Oxytocin (O)[a]	Depotocin (D)[b]	Control (C)	C - O	C - D	O - D
1 (gilts)	573	769	675	102	-94	-196
2	894	798	832	-62	34	96
3+	724	817	576	-148	-241	-93
Total	690	799	661	-29	-138	-109

[a]Fecundity index (farrowing rate x litter born live) is calculated from the data in Table 7.
[b]5 IU (1 mL) of oxytocin was added to 80 mL of semen at time of insemination.
[c]5 IU (.5 mL) of Depotocin was added to 80 mL of semen at time of insemination.
Reference: Biologizac a Chemizace Zivocisne Vyroby-Veterinaria 20(2):181-191, 1984.

Table 9. Effect of oxytocin on farrowing rate and litter size born live of sows bred artificially by experienced and inexperienced technicians.

Item	Inexperienced technicians[a]	Experienced technicians	Main effect of treatments
Farrowing rate, %			
Control	78.1[c] (78)	87.2[d] (172)	85..3[e]
Oxytocin[b]	90.2[d] (84)	92.2[d] (166)	92.4[f]
Difference	12.1	5.0	7.1
Average number piglets born live			
Control	9.4[c] (78)	10.1[d] (172)	9.9[e]
Oxytocin	10.2[d] (84)	10.5[d] (166)	10.4[f]
Difference	.8	.4	.5

[a]Inexperienced technicians had performed less than 25 artificial matings at the beginning of the experiment.
[b]Intramuscular injection of 5 IU of oxytocin 2 to 5 minutes before artificial insemination
[cd,ef]Values with different superscripts in the same column and reproductive trait are different.
([cd]P < .05; [ef] P < .1)
Reference: North Carolina State University Annual Swine Report, pp 89-90, 1995.

born live per litter was significantly different (P < .05) between gilts inseminated with oxytocin-treated semen (6.83 piglets) and Depotocin-treated semen (9.00). In Parity 2 females, sows inseminated with oxytocin-treated semen had a significant increase (P < .05) in average number of piglets born live per litter compared to sows inseminated with Depotocin-treated semen (10.0 vs 9.0). The average number of piglets born live per litter was not different between Parity 3 and greater sows inseminated with oxytocin-treated or Depotocin-treated semen.

The FI was 196 pigs less for gilts inseminated with oxytocin-treated semen compared to gilts inseminated with Depotocin-treated semen (Table 8). In Parity 2 females, the FI was 96 pigs greater for sows inseminated with oxytocin-treated semen compared to Depotocin-treated semen (894 vs 798). In Parity 3 females, the FI was 93 pigs less for sows inseminated with oxytocin-treated semen compared to sows inseminated with Depotocin-treated semen. When all parities are combined within treatment, females inseminated with oxytocin-treated semen had 109 less pigs per 100 sows compared to females inseminated with Depotocin-treated semen.

Effect of Technician

A study conducted by North Carolina State University evaluated the effect of injecting 5 IU of oxytocin intramuscularly at 2 to 5 minutes before AI on farrowing rate and litter size (Table 9). Farrowing rate was increased by 12.1 percent (P < .05) and litter size born live by .8 pigs (P < .05) when inexperienced people injected oxytocin before inseminating females compared to inexperienced people not injecting oxytocin. Although not significantly different, the farrowing rate and average number of pigs born live per litter was greater when experienced people injected oxytocin as compared to experienced people not injecting oxytocin.

(Continued on next page)

Age of Sperm Cells

Significant improvements (P < .05) have been found in farrowing rate and litter size when 5 IU of oxytocin is injected into the muscle at 2 to 5 minutes before insemination when using sperm cells stored in Beltsville Thawing Solution for more than 72 hours (Table 10). Farrowing rate was improved by 17 percent and litter size by .07 piglets. The average motility score of the sperm cells was 45.7 ± 5.8%.

Method of Using Oxytocin

An experiment in Spain studied the effect of adding 4 IU of oxytocin (Oxyvet®) to 100 mL of extended semen just before insemination or injecting 4 IU of oxytocin in the mucosa of the vulvar lips just before insemination on farrowing rate and total litter size born (Table 11). Farrowing rate and litter size were not significantly different when sows were inseminated with oxytocin-treated semen or injected with oxytocin in the vulva. However, the overall farrowing rate was 5.7 percent greater for sows inseminated with oxytocin-treated semen compared to sows injected with oxytocin immediately before insemination. The overall litter size was 11.50 pigs for sows inseminated with oxytocin-treated semen and 10.97 pigs for sows injected with oxytocin at the time of insemination.

Influence of Season

The addition of 4 IU of oxytocin to semen just before insemination resulted in a significant (P < .05) increase in farrowing rate for sows inseminated during the summer months (Table 11). Farrowing rate was not significantly increased during the summer months when 4 IU of oxytocin was injected in the vulva just before insemination. Sows inseminated during the summer months with oxytocin-treated semen or injected with oxytocin at time of insemination had larger (P < .001) litters than control sows. Although the use of oxytocin during winter, spring and fall did not significantly increase farrowing rate, litter size was significantly increased throughout the year. Oxytocin was mixed with the semen by gentle shaking.

Table 10. Effect of oxytocin on reproduction of sows bred with semen stored for > 72 hours in Beltsville Thawing Solution extender.

Item	>72 hours of storage	>72 hours of storage + used oxytocin[a]	Difference
Number of sows	55	59	-5
Farrowing rate, %	68.2[b]	85.2	-17
Number piglets born live per litter	9.4[b]	10.1	-.07

[a]5 IU of oxytocin was injected in the muscle 2 to 5 minutes before insemination.
[b]Values are different (P < .05) between treatments.
Reference: North Carolina State University Annual Swine Report, pp 89-90, 1995.

Table 11. Effect of oxytocin-treated semen and vulva injection of oxytocin on reproductive performance of sows.

	Farrowing rate, %			Average total number piglets born per litter		
	Oxytocin injected			Oxytocin injected		
Season	In semen[a]	In vulva[b]	Control	In semen	In vulva	Control
Jan to Mar	88.5 (61)[c]	92.9 (56)	87.3 (71)	12.2[x]	10.8[x]	10.1[y]
Apr to Jun	86.4 (59)	80.7 (62)	76.7 (60)	11.9[d]	11.3[d]	10.1[e]
Jul to Sep	73.0[D] (63)	56.3[DE] (64)‘	54.4[E] (57)	10.8[x]	10.5[x]	8.5[y]
Oct to Dec	84.4 (64)	81.7 (60)	77.8 (63)	11.2[x]	11.3[x]	9.8[y]
Overall	83.0	77.3	74.9	11.50	10.97	9.66

[a]4 IU oxytocin added to dose of semen with an insulin syringe just before insemination.
[b]4 IU oxytocin injected in mucosa of vulvar lips with an insulin syringe at time of insemination.
[c]Number of females bred.
[de]Values with different superscript within row are different (P < .05).
[DE]Values with different superscript within row are different (P < .01).
[xy]Values with different superscript within row are different (P < .001).
Reference: Theriogenology 49:829-836, 1998.

Table 12. The influence of duration of insemination on reproductive performance.

Duration of insemination (minutes)	Semen treated with oxytocin			Control		
	Number females	Farrowing rate, %	Total pigs born	Number females	Farrowing rate, %	Total pigs born
	Gilts			Gilts		
2 to 3	2	100.0	11.50	2	100.0	10.50
4 to 5	92	82.6	9.56	96	87.5	10.16
6 to 7	180	77.8	8.75	152	72.3	8.60
8 to 9	39	89.7	8.91	46	73.9	5.32
	Multiparous sows			Multiparous sows		
2 to 3	17	100.0	11.00	18	94.4	13.06
4 to 5	230	87.4	11.09	237	90.7	11.47
6 to 7	125	89.6	11.49	122	86.1	10.74
8 to 9	5	80.0	13.75	8	87.5	7.43

Reference: Archiv fur Experimentelle Veterinarmedizin 31(4):561-566, 1977.

Duration of Insemination

The duration of semen intake was not affected by adding 5 IU of oxytocin to semen. In gilts, the duration of

Table 13. Summary of benefit from using oxytocin in conjunction with artificial insemination.

Study	Farrowing rate	Piglets born live	FI[a] per 100 sows	Profit at $10/head	Cost of oxytocin[b]	Net gain per 100 sows
A	+5.8	+.82	+132	+$1,320	$2.00	+$1,318
B	+1.2	+.04	+15	+$150	$2.00	+$148
C	+3.0	-.20	+15	+$150	$2.00	+$148
D	-5.8	+.50	-14	-$140	$2.00	-$142
E (gilts)	+6.3	+.04	+54	+$540	$2.00	+$538
E (sows)	-.80	+.14	+5	+$50	$2.00	+$48
F (gilts)	-1.8	-.10	-22	-$220	$2.00	-$222
F (sows)	+4.2	+.20	+57	+$570	$2.00	+$568
G (gilts)	-.74	-.12	-14	-$140	$2.00	-$142
G (sows)	+3.5	+.54	+72	+$720	$2.00	+$718
H (gilts)	+.10	+.10	+9	+$90	$2.00	+$88
H (sows)	+1.1	+.11	+20	+$200	$2.00	+$198
I (gilts)	-1.36	-1.09	-102	-$1,020	$2.00	-$1,022
I (sows)	+4.08	+.85	+107	+1,070	$2.00	+$1,068
J (Inexp. person)	+12.1	+.8	+186	+$1,860	$2.00	+$1,858
J (Exp. person)	+5	+.4	+87	+$870	$2.00	+$868
K (old semen+oxy)	+17	+.07	+219	+$2,190	$2.00	+$2,188
L (oxy in semen)	+8.1	+1.84	+231	+$2,310	$2.00	+$2,308

[a]FI is fecundity index.
[b]$4.00 per 100 mL of oxytocin (20 IU per mL); 5 IU per dose; 1¢ per dose; 2 doses per sow.

insemination averaged 5.8 minutes for females inseminated with oxytocin-treated semen and 5.9 minutes for control females. The duration of insemination averaged 5.1 minutes for both sows inseminated with oxytocin-treated semen and control sows. The influence of duration of insemination on farrowing rate and total number of piglets born per litter is indicated in Table 12. In general, farrowing rate was greater for the shorter durations of insemination (2 to 5 minutes) than longer durations of inseminations (6 to 9 minutes). The addition of oxytocin to semen improved the farrowing rate of gilts when the duration of insemination was 6 minutes or longer.

Economics

Many studies did not find a statistically significant advantage for using oxytocin in conjunction with artificial insemination on farrowing rate or litter size born live; however, the majority of the studies showed a numerical increase in farrowing rate and litter size for sows inseminated with oxytocin-treated semen. A few studies found: (1) farrowing rate to be significantly improved without a significant improvement in litter size born live, (2) litter size to be significantly improved without a significant improvement in farrowing rate, (3) farrowing rate to be significantly improved only during the summer months, and (4) both farrowing rate and litter size to be significantly improved. Table 13 is a summary of the effect of using oxytocin in conjunction with artificial insemination on farrowing rate and litter size for the studies presented.

Instead of evaluating the economic benefit of oxytocin on individual traits (farrowing rate and litter size), it is better to make an economic evaluation based on an FI. An FI is the product of farrowing rate times litter size; thus, the FI helps determine the overall effect of using oxytocin in conjunction with artificial insemination on reproductive performance.

The cost of oxytocin per dose of semen is very cheap. For example, if the cost of 100 mL of oxytocin (20 IU per mL) is $4, the cost per dose of semen is 1 cent (5 IU of oxytocin per dose). The use of oxytocin was profitable in 77.8% of the data sets reported in Table 13. Three of the four data sets that had a negative effect on net gain per 100 females when using oxytocin used gilts.

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Extruded-Expelled Soybean Meal for Pigs

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Summary and Implications

A review of the value of extruded-expelled soybean meal (ESBM) for pigs was conducted. Results from two studies where the growth performance of weanling pig was evaluated suggested that the feeding value of ESBM relative to solvent-extracted soybean meal (SSBM) is not consistent. The economic value of ESBM relative to SSBM was estimated from pig performance data and the metabolizable energy content of corn, ESBM, and SSBM. When ESBM is used to replace 44% CP SSBM in growing-finishing pig diets, it is worth 0 to $36.29 per ton more than 44% CP SSBM, assuming 44% CP SSBM and corn cost $175/ton and $2/bushel, respectively. When ESBM is used to replace 46.5% CP SSBM in growing-finishing pig diets, it is worth 0 to $18.45 per ton more than 46.5% CP SSBM, assuming 46.5% CP SSBM and corn cost $175/ton and $2/bushel, respectively. Due to the higher fat content of ESBM, there is less dust generated when ESBM is handled compared to SSBM. Caution should be exercised when considering the purchase of ESBM due to the apparent quality variation until further evaluations on ESBM are completed.

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Introduction

Solvent-extracted soybean meal (SSBM) containing 44 to 46.6% CP and 1.5 to 3% fat is the most common source of supplemental protein used in pig diets. It is widely available and often produces the most economical gain when compared with other protein sources. Extruded-expelled soybean (ESBM), containing 43% CP and 7% fat, has become available in Nebraska recently. Previous research has shown that extruding raw soybeans makes them an acceptable source of supplemental protein for pigs. In addition, extrusion increases the dry matter and nitrogen digestibility of SSBM. The expeller reduces the oil content of extruded soybeans from about 18 to 7%. The objective of this study was to evaluate the economics of ESBM as a substitute for SSBM in swine diets. Because of limited research results available on ESBM, this is a progress report.

Nutrient Composition

A comparison of the nutrient composition of SSBM and ESBM is shown in Table 1. ESBM contains less total lysine than the SSBM, but similar concentrations of digestible lysine. Previous research at Kansas State University has shown that the digestibility of lysine in one source of ESBM is about two percentage points higher than the lysine in SSBM. The metabolizable energy (ME) level in ESBM is significantly higher than that in SSBM. The higher ME level in ESBM is due to two factors: the higher fat content of the meal and the extrusion process itself. Extrusion apparently increases the ME of ESBM because the ME of ESBM is higher than that predicted from its chemical composition. Diets made from ESBM contain 1 to 1.5% added fat (20 to 30 lb of added fat per ton of feed).

Performance Results

In the 1998 Nebraska Swine Report, the results of a study in which SSBM was compared to ESBM in the diet of segregated early weaned pigs were presented. In that study, diets containing ESBM and SSBM were formulated to contain the same concentration of ME and digestible lysine. In addition, the diets were formulated to contain the same lysine contribution from either ESBM or SSBM. Pigs fed the diet containing ESBM grew 22% slower and were 16% less efficient than pigs fed a diet containing SSBM during a 14-day study. In addition, energy, dry matter, and crude protein digestibilities were lower for the ESBM diet than the SSBM diet. The results of this study suggest that ESBM has a lower feeding value (84% if based on feed efficiency) than SSBM. In contrast, researchers at Kansas State University used a different source of ESBM and found the performance of weanling pigs fed diets containing ESBM was similar to that of those fed diets containing SSBM and added fat to equalize dietary energy density. They formulated the diets using the apparent ileal digestible amino acid coefficients and ME values for SSBM and ESBM obtained from a previous experiment. The results from these studies suggests there is significant variation in the feeding value of ESBM for pigs depending on the source of the ESBM.

Economic Considerations

We are not aware of any published research where the performance of pigs fed ESBM-based diets was compared to those fed SSBM-based diets that did not contain added fat to equalize dietary energy density. Nor are we aware of any economic analyses that producers who are not adding fat to SSBM-based diets can use to evaluate whether ESBM or SSBM is a better buy.

To calculate the economic value of ESBM as a replacement for either 44% CP or 46.5% CP SSBM in growing-finishing pig diets, 12 corn-based diets were formulated. All the diets were formulated using the ME and digestible lysine values for corn, SSBM and ESBM shown in Table 1. In addition, all diets were formulated to contain .81, .73, .65, and .55 % digestible lysine for pigs growing from 45 to 80, 80 to 130, 130 to 190, and 190 to 250 lb, respectively. Four diets were formulated with 43% CP ESBM and the level of ME was calculated for each diet. Four additional diets were made with 44% CP SSBM, but fat (3,616 kcal ME/lb) was added to match the ME level in the 43% CP ESBM diets. Likewise, four diets were made with 46.5% CP SSBM, but fat was added to match the ME level in the 43% CP ESBM diets. The percent of fat that was added to the 44% CP and 46.5% CP SSBM-based diets was 3.3 and 2.3, respectively. It was necessary to calculate the amount of added fat it would require to equalize energy density in the SSBM-based diets to the ESBM-based diets so we could estimate the improvement in feed efficiency of ESBM fed pigs. Based on previous research,

Table 1. Average nutrient composition of solvent extracted soybean meal (SSBM) and extruded-expelled soybean meal (ESBM).

Item	44% CP SSBM[a]	46.5% CP SSBM[b]	43% CP ESBM[c]
Dry matter, %	89	90	94
Lysine, %	2.83	3.00	2.70
Digestible lysine, %	2.41	2.55	2.45
Metabolizable energy, kcal/lb	1,445	1,535	1,741
Fat, %	1.5	3.0	7.0
NDF, %[d]	13.3	8.9	
Phosphorus, %	.65	.69	
Available phosphorus, %	.20	.16	

[a]National Research Council (1998).
[b]Adapted from NRC (1998).
[c]Dry matter, lysine, and fat values from Bruning Grain, Bruning, NE and metabolizable energy value from Kansas State University research.
[d]Neutral detergent fiber.

Table 2. Estimated added value ($/ton) of extruded-expelled soybean meal compared to 44% CP solvent-extracted soybean meal (SSBM) at various corn and SSBM prices.[a]

	Corn, $/bushel		
44% SSBM, $/ton	1.50	2.00	2.50
125	0 to 27.55	0 to 31.66	0 to 35.77
175	0 to 32.18	0 to 36.29	0 to 40.40
225	0 to 36.81	0 to 40.92	0 to 45.04

[a]A range is presented to compensate for quality variation.

Table 3. Estimated added value ($/ton) of extruded-expelled soybean meal compared to 46.5% CP solvent-extracted soybean meal (SSBM) at various corn and SSBM prices.[a]

	Corn, $/bushel		
46.5% SSBM, $/ton	1.50	2.00	2.50
125	0 to 14.38	0 to 18.25	0 to 22.12
175	0 to 14.59	0 to 18.45	0 to 22.32
225	0 to 14.79	0 to 18.66	0 to 22.53

[a]A range is presented to compensate for quality variation.

we assumed that feed efficiency is improved by 2 % for each 1% increment of added fat to the diet. Thus, growing-finishing pigs fed diets containing 43% CP ESBM should have a 6.6 % (3.3% x 2) and 4.6 % (2.3% x 2) better feed efficiency than pigs fed 44% CP and 46.5% CP SSBM-based diets without fat, respectively. An overall feed efficiency rate of 3.0 lb feed per lb of gain and an average daily gain of 1.8 lb was assumed for pigs fed the diets made from SSBM. The price of corn and SSBM were varied, whereas the price of other ingredients were at current market prices. The cost savings realized from improved feed efficiency were attributed to ESBM. No credit was given for better dust control or for any improvement in daily gain that may occur. To reflect results from the trial where ESBM in the diet reduced daily gain and feed efficiency, we assumed ESBM had no additional value compared to SSBM.

The estimated value of ESBM compared to 44% CP and 46.5 % CP SSBM in swine diets is presented in Tables 2 and 3, respectively. The estimated value of ESBM is represented as a range for each corn and SSBM price combination to reflect possible quality variation in ESBM. We intend for the range in prices to reflect the minimum and maximum value of ESBM compared to SSBM.

To use the tables locate the on-farm price of corn and SSBM. For example, assume the on-farm value of corn is $2/bushel and the on-farm cost of 46.5% CP soybean meal is $175/ton (Table 3). The table indicates that you could afford to pay up to $18.45 more for one ton of ESBM.

The premium you can pay for ESBM increases as corn and SSBM prices increase. The premiums are larger and they increase more rapidly for each $50 per ton increase in the price of 44% CP SSBM than for 46.5% CP SSBM, because we expect a larger improvement in feed efficiency (6.6 vs 4.6%) when ESBM is substituted for 44% CP SSBM than when 46.5% CP SSBM is replaced in the diet. Also, there is a significant range in the added value of ESBM for each corn and SSBM price combination. This variation is driven by an apparent difference in the feeding value of ESBM for pigs. These results show the need for additional research to determine if the extent of the quality variation used to calculate the premiums in this paper is representative of ESBM that is available to pork producers.

Dust Control and Flowability

Due to the higher fat content of ESBM, there is less dust generated when ESBM is handled compared to SSBM. In general, aerial dust concentration may be reduced 40 to 55% when ESBM is used to manufacture swine diets compared to SSBM. However, after the ESBM is included in the diet, it would be expected to reduce aerial dust by 10 to 15%. Reducing dust levels may improve the health status of people who work in feed mills and confinement buildings. Extruded-expelled soybean meal also flows from bulk bins easier than SSBM. The economic benefit of reduced dust level and better flowability may be significant in some situations. These attributes were not considered in our economic analyses.

Conclusion

Based on the limited amount of published data, it appears there is significant variation in the quality of ESBM for pigs. Therefore, it is difficult to provide accurate guidelines on what the value of ESBM is relative to SSBM. Producers are advised to use caution when buying ESBM. Efforts to more fully understand the value of ESBM in swine diets will be the focus of future research at the University of Nebraska.

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The Effects of Dietary Feather Meal Concentration and Space Allocation on Performance and Carcass Characteristics of Barrows

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Summary and Implication

*An experiment was conducted to determine the effect of dietary feather meal (**FM**, 0 and 20%) and space allocation (8.3 [**UC**] and 6.2 [**C**] ft²/pig) on growth and carcass characteristics of barrows. Control barrows (0% FM and UC) had 10% higher ADFI than gilts (0 % FM and UC), but only 2.6% greater ADG. Crowded barrows fed 20% FM diet from 165 lb to slaughter had decreased ADG and ADFI compared to control barrows. Crowded barrows fed a diet with no FM had a 4.9% reduction in ADFI compared to control barrows, and crowded barrows fed 20% FM diet had an ADFI (8.3% reduction compared to control barrows) similar to gilts. Gilts had improved feed efficiency compared to barrows. Control barrows reached market weight 7 days earlier than gilts, crowded barrows, and crowded barrows fed a 20% FM diet. Control barrows and gilts had similar average daily lean gain while crowded barrows fed 20% FM from 165 lb to slaughter had a decreased average daily lean gain. Gilts had less backfat and larger loin eye area than barrows on all treatments. Gilts also had a higher primal cut percentage and carcass lean percentage than barrows. Crowded barrows had a higher dressing percentage than uncrowded barrows. The combination of crowding and feeding feather meal reduced growth of barrows to a rate similar to gilts, but the improvements in backfat and carcass lean percentage observed previously by feeding feather meal to barrows were not observed in this study. Increasing stocking density is an effective method to decrease growth rate of barrows.*

Introduction

As more producers adopt all-in-all-out (**AIAO**) systems, the difference in growth rate between barrows and gilts is a concern. Barrows typically eat more feed, grow faster and reach market weight 7 to 10 days sooner than litter-mate gilts. Because barrows and gilts generally have similar lean growth potential in the finishing phase, barrows' greater feed intake results in fatter carcasses compared to gilts at the same live weight. Producers may be able to improve profitability if growth rate and carcass leanness of barrows can be modified to be similar to those of gilts. These modifications in barrows will improve pig flow in AIAO systems. Transportation costs and packer sort loss also may be reduced. Barrows with improved carcass leanness may be more profitable than typical fatter barrows. Our goal was to reduce daily gain of barrows to that of gilts without changing their daily lean gain, which should result in them having less backfat depth and leaner carcasses. Our previous studies have demonstrated that feather meal (a high-protein, low energy feed ingredient) decreased feed intake of finishing barrows, reduced carcass backfat depth and improved carcass leanness of finishing barrows. This article describes an experiment that was conducted to examine the interaction of space allocation and addition of feather meal to the diet on growth performance and carcass characteristics of barrows.

Procedures

Two hundred and fifty-five crossbred high-lean gain potential feeder pigs (210 barrows and 45 gilts with an average weight of 80 lb) were selected from the University of Nebraska Swine Research Unit herd. All pigs were weighed and assigned randomly to the experimental treatments on the basis of five weight outcome groups. Within outcome group, barrows were randomly assigned to one of four treatments and gilts were designated as the control group.

The experiment was conducted at the University of Nebraska Swine Research Unit at Mead. The pigs were housed in a partial slatted, single-wide, naturally ventilated barn with a deep pit. One nipple drinker and four feeder spaces were provided in each 5 × 16 ft pen with a total of 5 pens per treatment combination. Water sprinklers were used for summer heat relief. The feather meal was rendered from turkey feathers and determined by analysis to contain 84% crude protein, 93% dry matter, and 1.5% lysine.

The gilts (**CG**) were fed diets containing 0% FM and were housed 9 pigs per pen (8.3 ft²/pig). Experimental treatments for barrows were diets containing 0 or 20% feather meal and one of two space allocations (8.3 and 6.2 ft²/pig). Barrows with 8.3 (UC) or 6.2 (C) ft²/pig had 9 or 12 pigs per pen, respectively. Barrows assigned to the 0% feather meal treatments (**F0C** and **F0UC** treatments) were fed diets with no FM from approximately 80 lb to slaughter.

Table 1. Composition of experimental diets.

	80 to 135 lb		135 to 190 lb			190 to 245 lb		
Ingredient, %	Gilt	Barrow	Gilt	Barrow	20% FM[a]	Gilt	Barrow	20% FM[a]
Corn	73.65	76.45	77.90	81.50	60.00	82.85	85.65	65.00
Soybean meal, 46.5% CP	23.80	20.95	19.70	16.05	13.50	14.85	12.00	8.60
Feather meal	—	—	—	—	20.00	—	—	20.00
Tallow	—	—	—	—	4.10	—	—	4.10
Premix[b]	2.55	2.60	2.40	2.45	2.40	2.30	2.35	2.30
Formulated composition[c]								
CP, %	17.20	16.60	15.60	14.20	28.00	13.80	12.70	26.10
Ca, %	.54	.54	.50	.49	.50	.45	.45	.45
P, %	.48	.48	.43	.43	.43	.40	.40	.40
ME, Mcal/lb	1.51	1.51	1.51	1.51	1.51	1.51	1.51	1.51
Amino acids, %								
Lysine	.91(.78)[d]	.88(.71)	.79(.68)	.69(.59)	.86(.68)	.66(.56)	.58(.49)	.73(.56)
Tryptophan	.20(.18)	.20(.15)	.18(.16)	.15(.14)	.21(.18)	.15(.13)	.13(.11)	.18(.15)
Threonine	.66(.56)	.64(.46)	.60(.50)	.54(.45)	1.01(.84)	.52(.44)	.47(.40)	.94(.78)
Methionine + cystine	.60(.53)	.59(.48)	.56(.49)	.52(.46)	1.22(.96)	.51(.45)	.48(.42)	1.17(.92)

[a]Feather meal (FM) diet started the week the average pen weight was 165 lb or greater.
[b]The premix contained limestone, dicalcium phosphate, salt, vitamins, and minerals.
[c]CP = crude protein; Ca = calcium; P = phosphorus; ME = metabolizable energy.
[d]The values in parentheses are true ileal digestible amino acid percentages in the diet based on NRC values (1998).

Table 2. Performance and carcass criteria of barrows and gilts.

	Treatment[a]					CG vs	CG vs	UC[b] vs	0FM vs
Item	CG	F0C	F0UC	F20C	F20UC	F0UC	F20C	C	20FM
Pig Weight, lb									
Initial	80.6	80.8	81.1	80.2	80.8	NS[c]	NS	NS	NS
Final	242.0	239.6	240.1	236.3	240.5	NS	<.06	NS	NS
Growth Performance									
ADG, lb[d]	1.62	1.59	1.66	1.57	1.62	NS	NS	< .05	NS
ADFI, lb	5.10	5.35	5.61	5.18	5.46	< .01	NS	< .01	< .05
Gain/Feed	.318	.298	.297	.302	.298	< .01	< .05	NS	NS
Days to market	99.8	99.8	92.8	99.8	98.4	< .01	NS	< .05	
NS									
DLG, lb/d	.65	.61	.64	.60	.60	NS	<.05	NS	NS
Backfat[e] at d1,in	.30	.32	.31	.32	.31	< .05	< .05	NS	NS
Backfat at d90, in	.70	.78	.78	.80	.79	< .05	< .01	NS	NS
Carcass									
Hot carcass, lb	184.4	183.9	181.5	180.4	180.6	NS	NS	NS	NS
Dressing %	76.2	76.7	75.6	76.4	75.1	NS	NS	< .01	NS
Lean %[f]	51.59	49.22	49.22	49.32	49.10	< .01	< .01	NS	NS
Primal cut %	41.41	39.97	39.22	38.97	38.71	< .05	< .05	NS	NS

[a]CG = control gilts; F0C = crowded barrows fed 0% feather meal, F0UC = uncrowded barrows fed 0% feather meal, F20C = crowded barrows fed 20% feather meal, and F20UC = uncrowded barrows fed 20% feather meal.
[b]UC = F0UC + F20UC; C = F0C + F20C; 0FM = F0UC + F0C; 20FM = F20UC + F20C.
[c]Significance of main effect of treatments. NS = not significant.
[d]ADG = average daily gain; ADFI = average daily feed intake; DLG = daily lean gain.
[e]Determined by real-time ultrasound scan.
[f]Containing 5 % fat.

Barrows assigned to the 20% feather meal treatments (**F20C** and **F20UC** treatments) were fed diets with no feather meal until 165 lb body weight and subsequently were fed diets containing 20% feather meal to slaughter. The control barrow group (**F0UC**) served as a benchmark to evaluate the effect of treatments. The CG group served as a benchmark to evaluate the overall performance of barrows versus gilts.

All diets in each phase were formulated to contain the same metabolizable energy (Table 1). Diets were formulated to meet or exceed the NRC (1998) requirements for high-lean gain barrows and gilts. The diets containing 20% feather meal were formulated to have the same percentage of true ileal digestible lysine as diets fed to gilts because we anticipated that barrows fed these diets would have feed intake similar to that of gilts.

Real-time ultrasound scans were performed at beginning and day 90 of the experiment to determine the backfat depth of pigs. Pens of pigs were slaughtered the week the average pen weight was 236 lb or greater. Carcass

(Continued on next page)

characteristics were measured on individually identified pigs at slaughter using total body electrical conductivity (TOBEC) at SiouxPreme Packing Co., Sioux Center, Iowa.

Results and Discussion

There were no interactions between effects of feather meal and space allocation for any of the performance variables. Control barrows (F0UC) consumed 10% more feed (P < .05) and grew 2.5% faster than gilts (Table 2). Gilts needed 7 additional days (P < .05) to reach market weight and had better feed efficiency (P < .05) than control barrows. Control barrows and gilts had similar daily lean gain, but control barrows had greater backfat depth at 90 days (P < .05). Gilts had higher (P < .05) total carcass lean percentages and primal cut percentages than control barrows. Crowded barrows fed 20% FM diet from 165 lb to slaughter (F20C) had 8.3% less feed intake (P < .05) and grew 5.7% slower (P < .05) than control barrows, but their ADFI and ADG were similar to control gilts (P > .1) and they reached market weight at the same rate as gilts. Barrows consuming the F20C treatment also had lower daily lean gain than control barrows and gilts (.60, .64, and .65 lb/day, respectively) and greater backfat depth than gilts (P < .05). The carcass characteristics of crowded barrows fed 20% FM were similar to control barrows and both were fatter (P < .05) than control gilts.

Barrows fed no FM (F0C and F0UC) had ADG similar to gilts (Table 2). Barrows fed the 20% FM diet had less ADFI (P < .05) compared to barrows fed no FM. Other performance traits of barrows fed 20% FM were not different than barrows fed no FM. Gilts had better feed efficiency than barrows (P < .05) regardless of whether barrows were fed FM. Barrows fed 20% FM diets had reduced daily lean gain (P < .05) compared to gilts, but their lean gain did not differ from that of barrows fed no FM. Gilts had less backfat depth and leaner carcasses than barrows (P < .05), and there was no difference in carcass characteristics for barrows fed 0% and 20% FM diets. While there was no effect of FM on ADG and ADFI, daily lean gain of barrows fed the 20% FM diet was reduced compared to gilts (P < .05).

Crowded barrows had decreased ADG and ADFI (P < .05) compared to uncrowded barrows and needed more days (P < .05) to reach market weight. Gilts had an 8.4% reduction in ADFI and 7.1% better feed efficiency compared to uncrowded barrows (P < .05). Although crowded barrows reached market weight at the same time as gilts, they had lower daily lean gain (P < .05). Uncrowded barrows also tended to have lower daily lean gain than gilts (P = .1). Restricting space did not improve barrows' carcass leanness. Gilts had less backfat depth, higher carcass lean percentages, and greater primal cut percentages (P < .05) than barrows regardless of the space allocation.

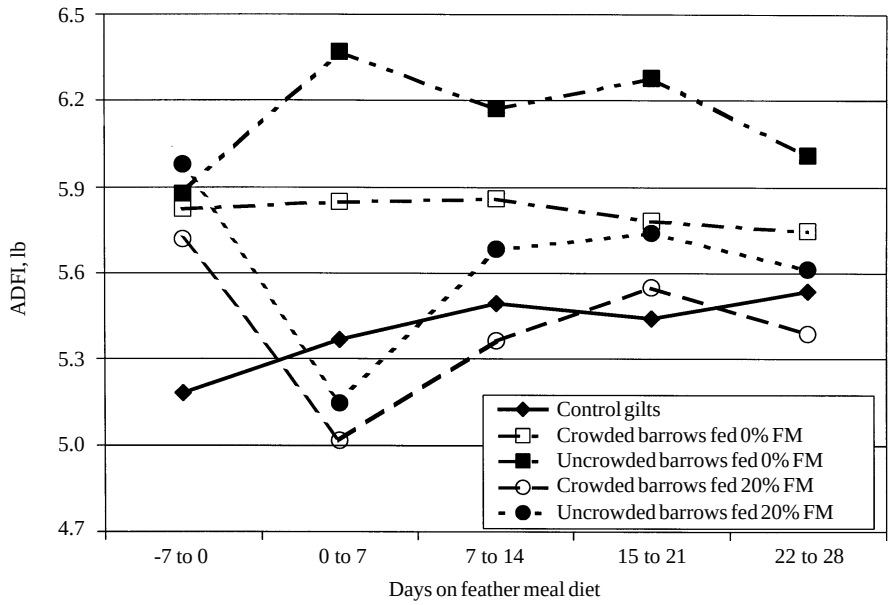

Figure 1. Change in Feed Intake due to Dietary Feather Meal Addition.

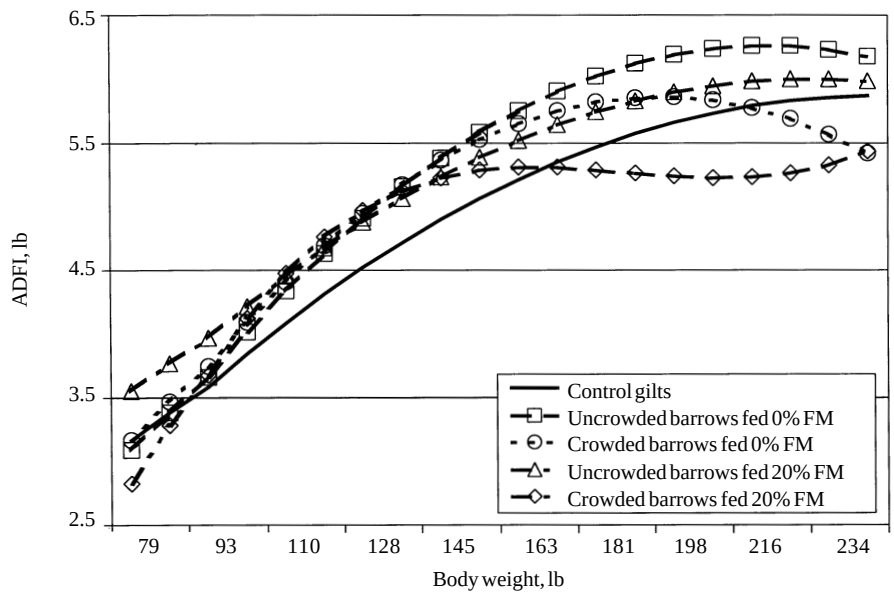

Figure 2. Effect of Experimental Treatments on Daily Feed Intake - data from Table 3.

Crowded barrows had higher dressing percentage ($P < .05$) than uncrowded barrows. The possible explanation for this improvement may be that reduction in feed intake reduced the size of organs involved in digestion and metabolism.

Average daily feed intake during the first week barrows were fed the 20% FM diet was less than that of gilts (Figure 1). The crowded barrows that received a 20% FM diet (F20C) had a 26.9% reduction in ADFI compared to control barrows and 7% reduction in ADFI compared to control gilts. From the second to fourth week after switching to FM diet, the ADFI of crowded barrows fed the 20% FM diet was similar to gilts. This change in ADFI is similar to our previous research trials in which ADFI started to increase beginning two weeks after barrows were fed a FM diet.

Uncrowded barrows (F0UC and F20UC) had higher ADFI than gilts from 80 to 240 lb body weight (Figure 2). Crowded barrows fed no FM started to have ADFI less than control barrows when their body weight was 141 lb and started to have ADFI less than gilts when their body weight was 216 lb. Crowded barrows fed 20% FM diet had ADFI lower than gilts when they were switched to FM diet at 165 lb body weight and then they had very constant ADFI until slaughter. Based on these regression equations (Table 3), crowded barrows fed 20% FM diet had 10.8% lower ADFI than gilts and 19.7% lower ADFI than control barrows at 220 lb body weight. This suggests that the reduction in the barrows' ADFI may have resulted in decreased intake of one or more nutrients which were critical for lean growth from 165 lb to slaughter. Therefore, protein synthesis may have decreased due to insufficient nutrient intake and energy not used for protein synthesis was stored as body fat.

Table 3. Regression equation of ADFI on body weight for each dietary treatment.

	Treatment[a]				
Item	CG	F0C	F0UC	F20C	F20UC
a[b]	-.028830[c]	-.809826[d]	-.697647[c]	-3.814061[d]	.124939[c]
b	.048661[d]	.078336[d]	.071218[d]	.223488[d]	.049956[d]
c	-.000220[d]	-.000442[d]	-.000358[d]	-.002646[d]	-.000240[d]
d	——	——	——	.000010305[d]	——
R square	.90	.90	.77	.80	.86

[a]CG = control gilts; F0C = crowded barrows fed 0% feather meal, F0UC = uncrowded barrows fed 0% feather meal, F20C = crowded barrows fed 20% feather meal, and F20UC = uncrowded barrows fed 20% feather meal.
[b]Equation: $Y = a + bx + cx^2 + dx^3$; Y = ADFI, kg; x = body weight, kg.
[c]$P > .1$.
[d]$P < .01$.

Thus, a possible explanation for no reduction in barrows' backfat depth when they consumed less feed may be an insufficient nutrient intake which was important for amino acid utilization and protein synthesis. This observation of a reduction in ADFI for crowded barrows fed 20% FM diet supports our explanation for the decreased daily lean gain of crowded barrows fed 20% FM diet because the barrows' ADFI was much lower than we expected it to be. While the 20% FM diet was formulated to contain the same percent of ileal digestible lysine as the gilt's estimated requirement, we might have underestimated the barrows' nutrient requirement when their ADFI was similar to that of gilts. In fact, we did underestimate the nutrient requirements for crowded barrows fed the 20% FM diet from 165 lb to slaughter because their ADFI was lower than that of control gilts.

Conclusion

Addition of 20% feather meal to the diet reduced barrows' ADG 2.5% and ADFI 3% when fed from 165 lb body weight to slaughter, while crowding reduced barrows' ADG 3.8% and ADFI 4.9% from 80 lb to slaughter. The combination of dietary FM and space allocation treatment reduced barrow's overall ADFI to a level similar to gilts. The reduction was due to a 26.9% reduction in ADFI after barrows were switched to feather meal diet at 165 lbs body weight. Their ADFI remained consistent from then to slaughter. But the rate of lean gain of crowded barrows fed the 20% FM diet also was decreased. These data suggest crowding was more effective in decreasing barrows' growth rates than dietary feather meal additions.

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A Review of the Ammonia Issue and Pork Production

Janeth J. Colina
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Phillip S. Miller[1]

Summary and Implications

During the last few decades, an increasing interest in, and respect for, the environment has arisen. This has consequences for livestock production. Air can become polluted by noxious odors from animal husbandry. A particular example is odor emission from pig buildings, because in several parts of the world pig production has become highly specialized, industrialized and concentrated geographically. Air quality in pig facilities, as it influences the well-being of animals and workers, has become a major concern for pork producers. Odors emanating from pig slurry are an increasing source of environmental pollution as well as a nuisance to the human population in the vicinity. Emission regulations that establish a maximum acceptable emission rate for individual pollutants released from a source are currently under debate for production agriculture in several regions throughout the United States. To meet increasingly stringent air quality demands, pork producers will be obligated to adopt technologies and innovations in production to minimize the concentration of pollutants present in the odor emitted from pig facilities. The purpose of this review is to discuss how ammonia is produced, the human health concerns involved, and the control of ammonia and odor emission.

How Ammonia is Produced

The first step in air quality maintenance associated with livestock production is the definition of sources responsible for the emission. Odor emission from swine facilities is due to fermentation of manure. Pig manure is predominantly a mixture of urine and feces, and contains undigested components of the diet, endogenous end products of digestion, and bacteria from the lower gastrointestinal tract. Manure contains a variety of simple and complex organic compounds and inorganic compounds, and may contain feed additives, depending on the dietary components. Odorous volatile organic compounds can be produced. The gases of most concern in swine buildings are ammonia, carbon dioxide and hydrogen sulfide. These gases are a major source of indoor air contamination. Ammonia is a gas with a very sharp odor. The odor is familiar to most people because ammonia is used in smelling salts and household cleaners. A major source of ammonia emission is the metabolic processes of producing urea, which is excreted via urine. Urea is converted into ammonia and carbon dioxide by the enzyme urease, present in feces. The most important factors affecting this process are the urinary urea concentration, pH and slurry temperature. Ammonia volatilization is a process that depends on factors such as concentration of ammonia, air speed in the building and ammonia and dry matter content in the manure. Most of the ammonia in the environment comes from the natural breakdown of manure and from dead plants and animals.

Health Concerns About Ammonia Emission

Excessive ammonia levels inside swine facilities can pose a direct hazard to animal caretakers and the animals themselves. The Agency for Toxic Substances and Disease Registry and the Environmental Health Center have reported several harmful effects of ammonia emission on human health when people are exposed to much higher than normal concentrations in swine buildings where the air is poorly ventilated. These effects include coughing, eye irritation, lacrimation, a burning sensation, laryngitis, severe pulmonary and gastrointestinal irritation, nausea and vomiting, diarrhea, abdominal pains, pulmonary edema, dyspnea, bronchospasm, chest pain, blisters and cold and clammy skin. Ammonia gas releases heat as it dissolves and can cause thermal injury. Exposure to high concentrations of ammonia produces severe burns of the cornea and upper airway. Populations at special risk of exposure to ammonia include individuals with reduced liver function, corneal disease, glaucoma or chronic respiratory diseases. Individuals who spend several hours each day in swine facilities risk suffering some of these symptoms if the air quality inside buildings is poor.

Ammonia emission also affects animal health. Ammonia can cause tissue damage in swine farms where pigs are confined. Ammonia levels of 50 ppm for three hours can produce coughing; eye, mouth, and nose irritation; and poor weight gain and feed intake in pigs. These effects can reduce growth performance, pig survival and sow reproduction. Although the current standard for safe ammonia levels is 25 ppm, recent research reports indicate that maintaining a level of no more than 10 ppm may help prevent health risk in both pigs and humans.

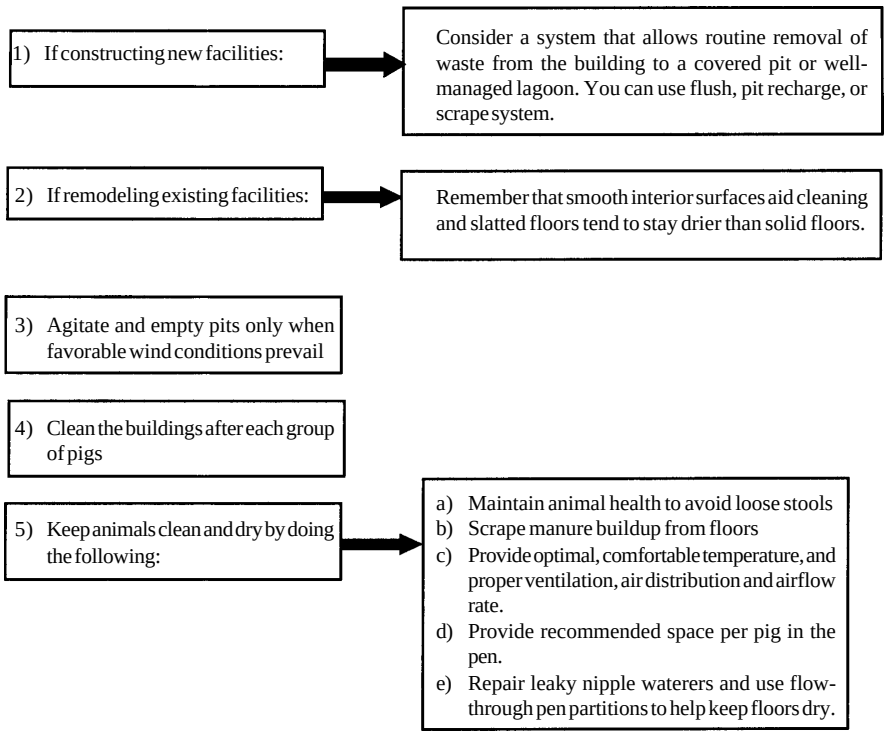

Figure 1. Recommendations that can be considered by pork producers to reduce odor emission in swine farms.

Regulations about Ammonia Levels

The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit for ammonia of 50 ppm, or 35 mg/m^3, time-weighted average, and a short-term (15 min) exposure limit of 35 ppm for ammonia. The National Institute for Occupational Safety and health (NIOSH) recommends that the concentration in workroom air be limited to 50 ppm for five minutes of exposure.

Under the Emergency Planning and Community Right-to-Know Act, releases of more than one pound of ammonia into the air, water and land must be reported annually and entered into the National Toxic Release Inventory. Emission regulations establishing a maximum acceptable emission rate for individual pollutants released from a source are currently under debate for production agriculture in several regions in the United States. To meet increasingly stringent air quality demands, individual pork producers will be obligated to adopt technologies and changes in production design that minimize the concentration of pollutants in the emissions stream from swine facilities. The National Pork Producers Council has indicated that there are no federal regulations directly related to the control of odors from swine facilities. The concern is about state and local laws and ordinances relative to odors. There also is a law of common nuisance, however, which roughly states that every person has the right to the enjoyment of his/her property without unreasonable interference. It is this nuisance law that has been of greatest concern to pork producers as they have dealt with the perception of odor problems from their farms.

Alternatives to Reduce Ammonia and Odor Emission from Swine Facilities

Although ammonia is neither the only source of odor nor the most offensive, studies in Europe have indicated that measures applied to reduce ammonia generally reduce odors from the other compounds as well. In land application of manure, for example, reducing ammonia emissions by 10 units was found to reduce odor by 70 units.

Procedures such as reducing the concentration of ammonia in the slurry (dilution), reducing the temperature of the slurry (cooling), reducing the emitting surface and reducing the pH (acidification) are principles proposed to reduce ammonia emission. Other alternatives include dietary manipulation including: a) lowering dietary crude protein and supplementing with crystalline amino acids, b) adding fiber sources such as small amounts of soybean hulls or dried sugar beet pulp to lower crude protein, c) adding calcium salts and feed additives such as sarsaponin, a natural extract of the yucca plant, which has been shown to reduce ammonia.

Some recommendations from The Department of Agricultural and Biological Engineering at Purdue University that can be considered by pork producers to reduce odor emission in swine farms are in Figure 1.

Current Research

The University of Nebraska-Lincoln Department of Animal Science has been researching methods to reduce ammonia emission from swine facilities. We have previously demonstrated that reducing dietary crude protein concentration can produce a major reduction in odor and ammonia in swine facilities. Currently, we are studying modifications in nursery diets to reduce ammonia and hydrogen sulfide gases. Feed additives that are being investigated are *Yucca schidigera* extract and calcium chloride. This research offers additional possibilities for reducing ammonia and odor emission from pig facilities.

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Nitrogen Balance and Growth Trials With Pigs Fed Low-Crude Protein, Amino Acid-Supplemented Diets

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Summary and Implications

To find out why low-crude protein, amino acid-supplemented diets often reduce growing pig performance, we conducted two experiments. In the first experiment, a nitrogen balance trial, three standard corn-soybean meal diets and three corresponding low-crude protein, amino acid-supplemented diets were used. The diets were: 14% CP and 10% CP + AA, 16% CP and 12% CP + AA, and 18% CP and 14% CP + AA, fed to 12 (90 lb) gilts in three periods of 7 d each. The amino acids lysine, tryptophan, threonine and methionine were added to low-crude protein diets to reach the same total amount as that in their respective standard diet. All nitrogen balance variables studied were affected by the reduction of crude protein in the diets. For energy balance, only energy excreted in feces and the apparent digestibility of energy were affected by the concentration of crude protein in the diet. The second experiment was a growth performance trial, in which a standard corn-soybean meal, 16% crude protein, and five low-crude protein, amino acid-supplemented diets were fed to 36 (43 lb) gilts. The low-crude protein diets had 15, 14, 13, 12, and 11% crude protein, and were supplemented with crystalline lysine, tryptophan, threonine, and methionine to contain the same total concentration as that in the standard diet. There was no difference in average daily gain, average daily feed intake, feed/gain, longissimus muscle area, or average daily lean gain in gilts fed 12 to 16% crude protein diets. However, the 11% crude protein diet had negative effects on these variables. Plasma urea nitrogen increased as the crude protein increased from 11 to 16%. Backfat thickness was not affected by the crude protein concentration in the diet, but varied among the different diets. These results suggest that dietary crude protein can be reduced from 16 to 12% if amino acids are added, without affecting pig performance, and that this crude protein reduction can help reduce nitrogen excretion in the urine and feces.

Introduction

Modern pig production faces the dual challenges of producing pork efficiently and profitably and avoiding environmental contamination with waste materials, especially with nitrogen-containing products in manure. One method that can reduce nitrogen excretion is to reduce the protein concentration of the diet. However, when the crude protein is reduced from 16 to 12% for growing pigs, the reduction in essential amino acids can reduce growth performance. To avoid the reduction in growth performance, the limiting essential amino acids (generally lysine, tryptophan, threonine and methionine) are supplemented to meet the pig needs. Some research has shown no difference in growth, nitrogen retention, or carcass quality when pigs are fed reduced-protein, amino acid-supplemented diets. But, other research has shown reduced performance with the low-crude protein, amino acid-supplemented diets compared to the intact protein counterpart.

Materials and Methods

To find out why low-crude protein, amino acid-supplemented diets do not always produce the same results with growing pigs as standard corn-soybean meal diets, we conducted two experiments. In Experiment 1 (a nitrogen balance trial) 12 crossbred, 90-lb live weight, gilts were fitted with urinary catheters one week before the beginning of the experiment. The gilts were individually penned in metabolism crates and fed a specific sequence of diets during three periods of seven days each (one diet in each period). The diets (Table 1) were three standard corn-soybean meal diets with 14, 16, and 18% CP, and each one had a low-crude protein, amino acid-supplemented counterpart with 4% CP less: thus, they had 10, 12, and 14% CP, respectively. The amino acids added were lysine, tryptophan, threonine and methionine. These amino acids were added to restore the total concentration to have the same level as their corresponding standard diet. Nitrogen digestibility, biological value and nitrogen balance were determined by measuring nitrogen intake and nitrogen excretion in feces and urine. Average daily gain, feed intake and feed/gain also were calculated. Creatinine and urea in urine were determined using automated laboratory procedures. Gross energy was determined in feed, feces and urine to calculate the apparent energy balance.

In Experiment 2 (a growth performance trial), 36 crossbred gilts were individually penned and fed one of six diets for 35 days, starting at 43 lb and finishing at 103 lb. The experimental diets (Table 2) were: a control, standard corn-soybean meal, 16% CP diet and five low-crude protein, amino acid-supplemented diets, with 15, 14, 13, 12, and 11% CP, with crystalline amino acids added to equal those in the 16% CP diet. The amino acids added were lysine, tryptophan, threonine and methionine. Feed intake, average daily

Table 1. Diet composition in Experiment 1.[a]

	Crude protein concentration					
Ingredients, %	14%	10% + AA	16%	12% + AA	18%	14% + AA
Corn	79.60	91.06	74.33	85.73	69.21	80.63
Soybean meal (46.5% CP)	15.65	3.10	20.96	8.50	26.19	13.70
Dicalcium phosphate	1.25	1.55	1.20	1.50	1.10	1.40
Limestone	0.40	0.33	0.40	0.33	0.40	0.33
L-lysine•HCl	—	0.45	—	0.44	—	0.44
L-tryptophan	—	0.07	—	0.08	—	0.07
L-threonine	—	0.20	—	0.19	—	0.20
DL-methionine	—	0.13	—	0.13	—	0.13
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[b]	0.70	0.70	0.70	0.70	0.70	0.70
Trace mineral premix[c]	0.10	0.10	0.10	0.10	0.10	0.10

[a]As-fed basis.
[b]Supplied per kilogram of diet: retinyl acetate, 3,086 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15.4 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23 mg; choline chloride, 77 mg; vitamin B_{12}, 15.4 µg; ethoxyquin, 0.7 mg.
[c]Supplied (mg/kg of diet): Cu (as $CuSO_4 \cdot 5H_2O$), 11; I (as $Ca[IO_3]_2 \cdot H_2O$), .22; Fe (as $FeSO_4 \cdot H_2O$), 110; Mn (as MnO), 22; Se (as Na_2SeO_3), .3; Zn (as ZnO), 110.

Table 2. Diet composition in Experiment 2.[a]

	Crude protein concentration					
Ingredients, %	11%	12%	13%	14%	15%	16%
Corn	88.17	85.59	82.755	80.15	77.71	74.81
Soybean meal (49.1% CP)	5.60	8.40	11.45	14.30	17.00	20.25
Dicalcium phosphate	1.47	1.41	1.35	1.28	1.24	1.16
Limestone	0.60	0.61	0.65	0.66	0.65	0.68
L-lysine•HCl	0.55	0.45	0.35	0.25	0.15	0.00
L-tryptophan	0.09	0.08	0.065	0.05	0.03	0.00
L-threonine	0.25	0.21	0.17	0.13	0.08	0.00
DL-methionine	0.17	0.14	0.11	0.08	0.05	0.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	2.00	2.00	2.00	2.00	2.00	2.00
Vitamin premix[b]	0.70	0.70	0.70	0.70	0.70	0.70
Trace mineral premix[c]	0.10	0.10	0.10	0.10	0.10	0.10

[a]As-fed basis.
[b]Supplied per kilogram of diet: retinyl acetate, 3,858 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 19.3 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23 mg; choline chloride, 386 mg; vitamin B_{12}, 15.4 µg; ethoxyquin, 0.7 mg; folic acid, 1.5 mg; biotin, 0.077 mg.
[c]Supplied (mg/kg of diet): Cu (as $CuSO_4 \cdot 5H_2O$), 11; I (as $Ca[IO_3]_2 \cdot H_2O$), .22; Fe (as $FeSO_4 \cdot H_2O$), 110; Mn (as MnO), 22; Se (as Na_2SeO_3), .3; Zn (as ZnO), 110.

Table 3. Growth performance results, Experiment 1.

	Crude protein concentration					
Variable	14% CP	10% + AA	16% CP	12% + AA	18% CP	14% + AA
ADG[1], lb	1.81	1.61	1.75	1.50	1.55	1.37
ADFI, lb	3.18	3.74	3.68	3.49	3.11	3.16
F/G	1.76	2.33	2.11	2.33	2.01	2.31

[1]ADG: Average daily gain.
ADFI: Average daily feed intake.
F/G: Average daily feed intake/average daily gain.

gain and feed/gain were measured weekly. Backfat thickness and longissimus muscle area were measured by ultrasound on the first and the last day of the experiment. Plasma urea nitrogen was measured the first, the fourteenth, and the last day of the experiment. Lean gain was determined using the National Pork Producers Council equations.

Results and Discussion

Experiment 1

There was no effect of the concentration of crude protein in the diet on average daily feed intake (ADFI), average daily gain (ADG) and feed/gain ratio (FG) (Table 3), probably because each experimental period was only one week. Initial body weight and ADFI were used as covariates for all nitrogen and energy (Table 4) balance variables. Nitrogen intake, nitrogen retention, apparent digestibility of nitrogen, apparent digestibility of energy, excretion of nitrogen in feces and urine, concentration of urea in urine, and excretion of energy in feces increased ($P < .05$) as the crude protein increased in the diet, regardless of the type of diet. Biological value, creatinine concentration in urine, other nitrogen in urine, nitrogen retention percentage, energy intake, energy retention, energy retention percentage, and energy excretion in urine were not affected by the concentration of crude protein. Additions of the four crystalline amino acids were not effective in increasing nitrogen retention to the same level that was achieved by the gilts fed the corresponding intact protein diets. Although there were no significant differences in energy retention, the low-crude protein diets had higher energy retention in the 16 vs 12 + AA and 18 vs 14 + AA comparisons, but not in the 14 vs 10 + AA comparison. These results suggest that nitrogen retention in growing pigs responds up to the highest concentration of crude protein fed in this experiment (18%) and that other factors in addition to the

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amino acid concentration of lysine, tryptophan, threonine and methionine affect the nitrogen retention.

Experiment 2

There were no differences among gilts fed 16, 15, 14, 13, or 12% CP diets (Table 5) in average daily gain, feed/gain, longissimus muscle area, or average daily lean gain. However, there was a reduction in the response of these variables in gilts fed the 11% crude protein diet compared to the other five treatments (quadratic effect of protein, $P \leq .05$). Average daily feed intake and backfat thickness were not affected ($P > .05$) by diet, but there was a tendency for feed intake to increase as the crude protein increased from 11 to 14% and decrease above this concentration. There is no apparent explanation for this trend, because the energy concentration was similar in all diets. There was a numerical increase in the fat thickness of gilts fed the 12% crude protein diet compared with all other diets. Plasma urea nitrogen increased as the crude protein increased in the diet from 11 to 16% (linear effect of protein, $P < .001$). These results confirm that crude protein can be reduced from 16 to 12% if amino acids are added to the diet without affecting pig performance, and that this reduction in CP in the diet can help to reduce the nitrogen excretion in the urine and feces (based on the reduction in plasma urea nitrogen as the crude protein was reduced in the diet). The reduction in crude protein to less than 12% reduced growth rate, possibly because other amino acids (e.g., isoleucine, valine, histidine) were deficient.

Table 4. Nitrogen (g/d) and Energy (Mcal/d) balance results, Experiment 1.

	Crude protein concentration					
Variable	14% CP	10% + AA	16% CP	12% + AA	18% CP	14% + AA
Nitrogen intake[a]	36.12	26.37	40.37	30.75	44.48	35.21
Nitrogen retention[a]	20.98	15.82	24.53	19.18	27.10	21.50
Nitrogen retention, %	58.82	58.01	60.89	62.41	59.77	60.86
Apparent digestibility of nitrogen, %[a]	88.16	83.20	87.99	85.64	87.06	86.51
Feces nitrogen[a]	4.36	4.46	4.80	4.44	5.81	4.73
Urine nitrogen[a]	10.78	6.09	11.04	7.12	11.56	8.98
Urea urine nitrogen[a]	7.48	3.95	7.86	4.86	9.22	6.17
Creatinine urine nitrogen	0.72	0.67	0.58	0.58	0.57	0.71
Other urine nitrogen	2.46	2.04	2.71	1.76	1.74	1.95
Energy intake	6.220	6.060	6.170	6.243	6.215	6.257
Energy retention	5.483	5.312	5.336	5.469	5.346	5.416
Energy retention, %	88.22	87.67	86.35	87.59	86.01	86.67
Apparent digestibility of energy, %[a]	90.17	88.73	88.48	89.72	87.62	88.80
Feces energy[a]	0.618	0.684	0.705	0.643	0.767	0.705
Urine energy	0.122	0.105	0.121	0.118	0.114	0.135

[a]Linear effect of protein, $P < .05$.

Table 5. Growth performance results, Experiment 2.[a]

	Crude protein concentration					
Variable	11%	12%	13%	14%	15%	16%
Average daily gain, lb[b]	1.29	1.80	1.85	1.86	1.71	1.70
Average daily feed intake, lb	3.36	3.72	3.94	4.03	3.65	3.56
Feed/gain[b]	2.60	2.07	2.13	2.16	2.14	2.10
Longissimus muscle area, in^2 [c]	2.81	3.35	3.35	3.35	3.36	3.45
Backfat thickness, in	0.41	0.56	0.45	0.46	0.46	0.43
Average daily lean gain, lb[b]	0.47	0.64	0.69	0.68	0.64	0.65
Plasma urea nitrogen, mg/100 ml [d]	2.57	3.94	5.10	6.80	7.61	10.45

[a]Six individually fed gilts per treatment, 35-d experiment, average initial weight 43 lb, average final weight 103 lb.
[b]Quadratic effect of protein, $P < .01$.
[c]Quadratic effect of protein, $P < .05$.
[d]Linear effect of protein, $P < .001$.

Summary

The results of the nitrogen balance and growth trials are not consistent. In the growth trial, we were able to reduce the crude protein percentage by four units along with appropriate amino acid supplementation and maintain performance. This was not the case in the nitrogen balance experiment in which, regardless of the initial protein percentage (14, 16 or 18%), the low-protein, amino acid-supplemented diets supported less nitrogen retention. The reasons for this inconsistency are unknown. Nitrogen retention is a more sensitive trait than average daily gain or average daily lean gain, but that does not fully explain the differences we observed. We are currently conducting additional experiments to investigate these issues.

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The Use of Plasma Urea as an Indicator of Protein Status in Growing-Finishing Pigs

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Phillip S. Miller
Austin J. Lewis[1]

Summary and Implications

An experiment is being conducted on commercial swine operations to determine if plasma urea concentration can be used as an indicator of protein status in growing-finishing pigs. Swine producers in Eastern Nebraska are being selected to participate in this on-farm study. The experiment includes the completion of a 30-question survey and an on-farm visit for the collection of blood and feed samples. The survey includes questions about genetics, nutrition, housing and health. Preliminary results suggest that crude protein is overfed in most finishing diets. Gilts consistently have lower plasma urea concentrations than barrows when gilts and barrows are fed the same diet during the finishing growth period. This confirms the concept that gilts utilize protein more efficiently for lean growth. These results suggest that within an individual swine operation, plasma urea is a useful indicator of protein status in growing-finishing pigs.

Introduction

Because feed costs represent over one-half of production costs from weaning to market, producers must accurately formulate diets to meet the requirements of their pigs to minimize feed costs. Therefore, producers must continually update their swine feeding program and may need to adopt new techniques to improve the accuracy of determining nutrient requirements.

Adopting new methods to improve the estimation of protein requirements for pigs is important for several reasons. First, with the emergence of different commercial populations of pigs, protein requirements for each of these populations will be different because of differences in lean growth potential. Second, dietary protein concentrations must be formulated to maximize lean growth without providing excesses or deficiencies of amino acids that may decrease performance and/or increase production costs. Finally, each operation will have different protein requirements regardless of the genetic population of pigs due to differences in management practices, diseases (clinical and subclinical) and facilities. Because it is too expensive and time consuming for each operation to perform traditional feeding and carcass analysis experiments, a simple on-farm procedure to identify protein requirements for growing-finishing pigs is needed.

Plasma urea has been chosen as a potential indicator of protein status because urea is produced for removal of nitrogen from the body when excess amino acids are metabolized. Increased plasma urea concentrations may be due to an over consumption of protein by the pig, which would indicate an excess concentration of dietary crude protein. An experiment conducted in 1995 at UNL showed that the protein requirements of two populations of pigs in a research setting could be determined using plasma urea concentration. In the aforementioned experiment, low lean gain potential and modern Hampshire pigs with a medium to high lean gain potential were used. Based on the positive results of that experiment, the current experiment was designed to investigate whether plasma urea concentrations can be used as an on-farm index of the protein requirements of different populations of pigs.

Procedures

The experiment includes two parts. Part one is a 30-question survey completed by the producer. The survey includes four major sections with questions about genetics, nutrition, housing and health. The genetic section asks questions about seedstock suppliers, replacement gilts, determination of nutrient requirements and lean gain potential. This section also inquires about slaughter kill sheet data and production records. Information acquired includes backfat depth, loin depth, percent yield, percent lean, hot carcass weight, average weight at the beginning of the growing-finishing period, average slaughter weight, and days from start of the growing-finishing period to slaughter. Nutrition questions include protein and lysine concentrations fed in each diet, the amount of each diet provided, separate-sex feeding and type and amount of antibiotics used in the diets. The housing section questions pertain to type of facilities (confinement or outdoors), ventilation, space/pig, type of feeders and space/pig for feeders and waterers. The health section includes questions about facility biosecurity, pig flow, pig grouping, facilities cleaning, antigen exposure, visual symptoms of illness and percent death loss.

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The second part of this study is an on-farm visit. During the on-farm visit any questions pertaining to the questionnaire are answered. Blood samples are collected from 10 barrows and 10 gilts within each growth phase (nursery, growing and finishing). A diet sample is collected for each group of pigs sampled. The diet sample is analyzed for crude protein and plasma samples are analyzed for urea concentration.

Results

Currently, eight farms have been sampled with a total collection of 500 blood samples. The goal is to acquire at least 250 samples from five additional farms. Results from the analyzed samples show that gilts consistently have lower plasma urea concentrations than barrows when fed the same diet (Figure 1). Gilts fed a greater crude protein concentration in the growing stage (80 to 200 lb) have lower plasma urea concentrations than barrows. This indicates that gilts have improved use of protein for lean muscle deposition compared to barrows. Analyzed crude protein concentrations indicate that many pigs, especially in the finishing phase (200 to 270 lb), are overfed protein.

Survey results show that on average 2,400 pigs/year are sold per operation. Lean gain potential on most operations is considered to be in the high category (> .72 lb/d). Data from the kill sheets show that the average backfat depth is .78 inches, loin depth is 2.30 inches, lean percentage is 54.5, yield is 75.4 %, hot carcass weight is 187 lb, average weight at the beginning of the growing-finishing period (including nursery) is 12 lb, average weight at slaughter is 254 lb, and the number of days from the start of the finishing period to slaughter is 173. Separate sex feeding is used on most operations. The majority of pig flow is all-in-all-out in the nursery and growing-finishing facilities, with most pigs raised in mechanically ventilated confinement buildings. Space per pig in the nursery averaged 3.25 ft^2/pig and in the growing-finishing phase it averaged 8 ft^2/pig. All facilities are routinely high-pressure washed and disinfected between pig groups. Facility biosecurity was minimal (same site and labor, clean coveralls and boots) on most operations. Mycoplasmal hyopneumonia and Porcine Respiratory and Reproductive Syndrome are the two main diseases to which pigs are exposed. Average death loss in the nursery was 2 to 3% and during the growing-finishing period was 3 to 4%.

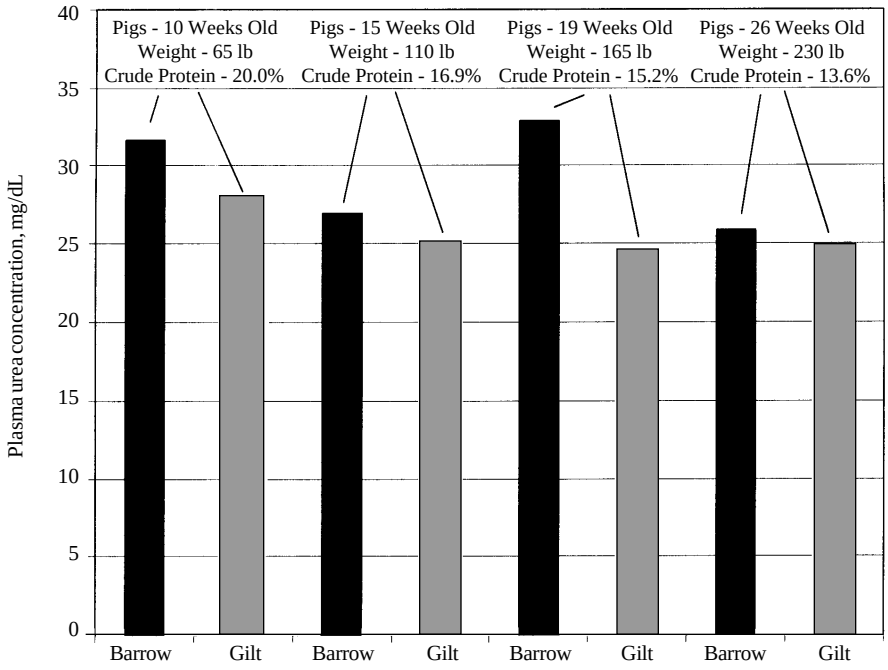

Figure 1. Example of gilts consistently having lower plasma urea concentrations than barrows when fed the same diet. Data derived from one farm. Dietary CP concentrations varied from approximately 13 to 20%.

Conclusions

Results from the on-farm study have produced similar results to those acquired from our research facilities. These results show that plasma urea concentrations have the potential to be used as an indicator of protein requirements of growing-finishing pigs. Plasma urea concentrations may also be used to determine the correct weight to change diets throughout the growing-finishing period. However, nutrient requirements are not the same for each growth phase on each operation and reflect variation in management, disease and facilities. This approach may assist producers to determine the correct nutrient density and the correct time to switch diets that will maximize growth and minimize production costs.

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The Effects of Compensatory Growth and Form of Amino Acid Supply on Plasma Urea Concentration, Organ Weights and Carcass Characteristics in Gilts

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

Summary and Implications

An experiment was conducted to examine the effects of compensatory growth and amino acid supply on plasma urea concentration, organ weights and carcass characteristics. Gilts were fed either a corn-soybean meal diet or a corn-soybean meal diet supplemented with crystalline lysine. Pigs were randomly allotted to either a 21-day ad libitum eating period or a 42-day restricted-realimentated feeding period. The restricted-realimentated feeding period consisted of a 21-day restriction period and a 21-day ad libitum eating period (realimentation). During the restriction period, pigs were fed to maintain body weight. During week one of the ad libitum period, gilts in the restricted-realimentated (RR) group gained weight 41% faster (P < .01), consumed 9% less feed (P < .01), and were 58% more efficient (P < .01) compared to gilts in the ad libitum (AL) group. Ultrasound scanning measurements showed that during the restriction period, gilts had a numerical decrease in backfat and a numerical increase in longissimus muscle area. Results show that the gilts in the RR group exhibited compensatory growth during the first two weeks of the ad libitum eating period. These results also suggest that during a restriction period growing pigs are able to utilize fat stores and repartition body protein to maintain lean muscle deposition.

Introduction

Compensatory or "catch-up" growth is characterized by a period of accelerated growth after a period of feed restriction. Carcass composition, organ size and metabolic activities are altered during a restriction-realimentation period. Therefore, examination of organ adaptations during feed restriction and the expression of accelerated growth rates during refeeding support the use of compensatory growth as a model of rapid growth in pigs.

The primary objective of this research was to investigate the effects of feed restriction and realimentation on the response of plasma urea concentration in gilts fed a traditional corn-soybean meal diet or a lysine-supplemented corn-soybean meal diet. The second objective was to examine organ adaptations and the gilt's ability to deposit lean tissue after a period of feed restriction.

Procedures

Forty-six crossbred gilts with an initial weight of 77 lb were used. Four gilts were randomly selected for an initial slaughter group to determine initial organ weights and carcass composition. Eighteen gilts were allocated to have ad libitum access to either a corn-soybean meal or corn-soybean diet with supplemental lysine. Within this group, six pigs, three from each diet treatment, were slaughtered during week one, two, and three of the experiment. Twenty-four gilts were offered a maintenance level of feed for 21 days. Feed allotments were adjusted every three

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days to minimize weight loss or gain. At the end of the 21-day feed restriction period, the restricted pigs weighted 77 lb. On day 21, six restricted gilts were randomly selected for slaughter. The remaining 18 gilts were allowed ad libitum access to either the corn-soybean meal or the lysine-supplemented diet until slaughter. Within this group, six pigs, three from each diet treatment, were slaughtered during weeks 4, 5, and 6 of the experiment. All pigs were individually penned in an environmentally controlled room.

Diets were corn-soybean meal based and formulated to contain one of two crude protein percentages (16.3 or 14.3%; Table 1). All other nutrient concentrations were equal to, or in excess of, NRC (1998) requirements. During the feed restriction period, gilts were fed the 16.3% CP corn-soybean meal diet. Daily feed allotments during the feed restriction period were based on each pig's maintenance energy requirement. Because nutrient densities were not adjusted during the restriction period, the daily intakes of all nutrients were less than NRC requirements for growth.

Pig weights were recorded weekly during the ad libitum period and every three days during the restriction period. Feed consumption was measured weekly for the ad libitum (AL) groups and daily during the realimentation period for the restricted-realimented (RR) groups. Blood samples were collected weekly for both feeding groups and daily during the first week of ad libitum feeding. Ultrasound scanning measurements were made weekly by a certified technician. Carcass measurements and organ weights were collected at slaughter. Gastrointestinal contents were removed for the determination of empty body weight (live weight minus gastrointestinal content weight).

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

Item	Corn-soybean meal	Corn-soybean meal + lysine
Ingredient, %		
Corn	74.02	77.85
Soybean meal (46.5% CP)	21.40	17.25
Tallow	2.00	2.10
Lysine	—	.15
Dicalcium phosphate	1.05	1.15
Limestone	.43	.40
Salt	.30	.30
Vitamin premix[a]	.70	.70
Trace mineral premix[b]	.10	.10
Calculated nutrient content		
Crude protein, %	16.30	14.30
ME, Mcal/lb	1.55	1.55
Lysine, %	.89	.89
Calcium, %	.65	.65
Phosphorus, %	.55	.55

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

Table 2. Performance of gilts fed a corn-soybean meal or lysine-supplemented, corn-soybean meal diet during two different feeding regimens.

Diets	Corn-soybean meal		Corn-soybean meal + lysine		P-Value[c]		
Feeding regimen[a]	AL	RR	AL	RR	FR	D	FR x D
Item[b]							
Week 1							
ADG	2.21	2.29	3.57	2.81	< .05	< .05	< .05
ADFI	4.41	4.40	4.05	4.02	< .05	NS	NS
ADG/ADFI	.50	.52	.88	.70	< .05	< .05	< .05
Week 2							
ADG	2.18	2.13	2.58	2.62	< .05	NS	NS
ADFI	4.89	4.69	5.39	5.77	< .05	NS	NS
ADG/ADFI	.45	.45	.48	.45	NS	NS	NS
Week 3							
ADG	2.71	2.21	2.36	2.91	NS	NS	< .05
ADFI	5.80	4.94	5.81	6.14	< .10	NS	< .10
ADG/ADFI	.47	.45	.41	.47	NS	NS	NS

[a]AL=ad libitum group, RR=restricted-realimentated group.
[b]ADG = average daily gain, ADFI=average daily feed intake.
[c]FR=feeding regimen, D=diet, and NS=nonsignificant effect, P > .10.

Results

Growth performance data are shown in Table 2. During week 1 and 2 of the ad libitum feeding period, average daily gain (ADG) was greater ($P < .05$) in the RR gilts compared to the AL gilts. There was a feeding regimen × diet interaction ($P < .05$) observed during week 3 of the ad libitum feeding period for ADG. Average daily feed intake (ADFI) for the AL gilts was about 9% greater ($P < .05$) during week 1 compared to the RR gilts. However, during weeks 2 and 3, the RR gilts consumed more ($P < .10$) feed than the AL gilts. A feeding regimen × diet interaction ($P < .05$) was observed during week 3 for ADFI, with the RR gilts fed the lysine-supplemented diet having the greatest ADFI. Feed efficiency was improved ($P < .05$) in the RR gilts during week 1 compared to the AL gilts. There was also a diet effect ($P < .05$) and a feeding regimen× diet interaction ($P < .05$) during week 1 for feed efficiency. During weeks 2 and 3, there were no differences in feed efficiency between the AL and RR gilts.

Ultrasound backfat (BF) and long-

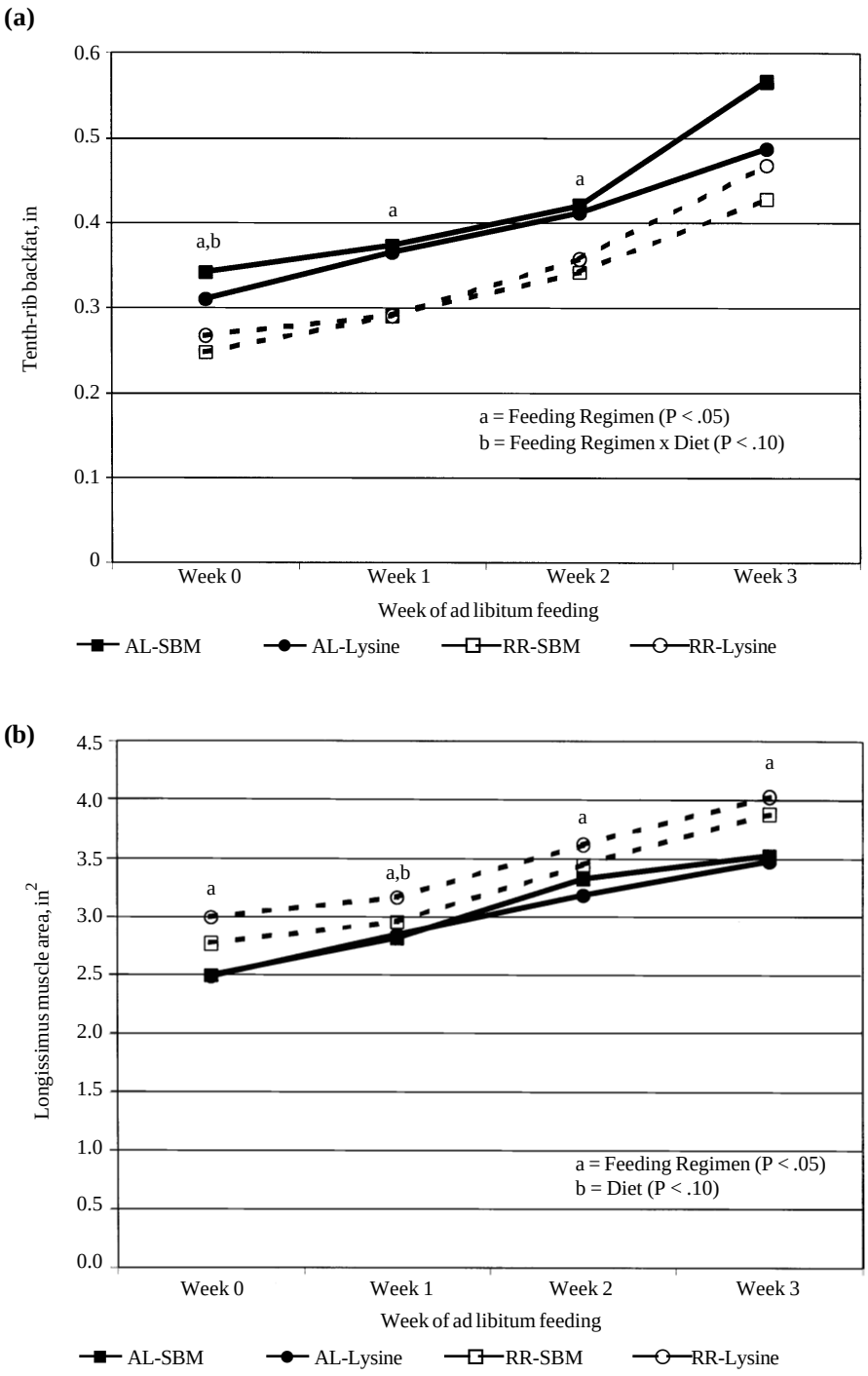

Figure 1. The response of a) backfat (BF) and b) longissimus muscle area (LMA) ultrasound measurements to feeding treatments (ad libitum, AL; restricted-realimentated, RR) and diet treatments (corn-soybean meal, SBM; lysine-supplemented, corn-soybean meal, Lysine).

issimus muscle area (LMA) measurements are shown in Figure 1a and 1b, respectively. Week 0 indicates the start of the ad libitum feeding period, which was day 0 for the AL gilts and day 21 for the RR gilts. Ultrasound measurements show that the RR gilts lost ($P < .05$) BF during the restriction period and continued to have less ($P < .05$) BF during weeks 1 and 2 of the ad libitum feeding period. Longissimus muscle area was greater ($P < .05$) in the RR gilts than in the AL gilts at the initiation of the ad libitum feeding period. During weeks 1, 2 and 3, RR gilts continued to have greater ($P < .05$) LMA than the AL gilts. A diet effect was observed during week 1, with the gilts fed the lysine-supplemented diet having a greater ($P < .05$) LMA than gilts fed the corn-soybean meal diet. Plasma urea concentrations were higher ($P < .05$) in gilts fed the corn-soybean meal diet than in gilts fed the lysine-supplemented diet (Figure 2). Also, plasma urea concentrations were greater ($P < .05$) in the RR gilts than in the AL gilts during days 1- 7 and day 20. This observation is surprising because ADFI was lower in RR vs AL pigs during the first week of ad libitum feeding.

Organ weights and carcass measurements are shown in Table 3. Livers of RR gilts were heavier ($P < .05$) than those of AL gilts during weeks 1 and 2 and were heavier ($P < .05$) in gilts fed the corn-soybean meal versus the lysine supplemented diet during week 1. There was a feeding regimen× diet interaction ($P < .05$) observed during week 2 of the ad libitum feeding period for liver weight. Pancreas weights were greater ($P < .05$) in the AL gilts than in the RR gilts during week 1 of the ad libitum period. A feeding regimen× diet interaction was observed in the second week of the ad libitum feeding period for pancreas weight. There were no differences between feeding or diet treatments for tenth rib BF. Longissimus muscle area was greater ($P < .05$) in the RR versus the AL gilts during week 1 and was greater ($P < .05$) in gilts fed the lysine-supplemented diet versus the gilts fed the corn-soybean meal diet during week 1. A feeding regimen× diet interaction ($P < .05$) was observed during week 1 with the gilts in the RR-lysine group having the largest LMA. There was a numerical increase in LMA for gilts fed the RR-lysine supplemented diet during weeks 2 and 3. Hot carcass weight was greater ($P < .05$) during

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Table 3. Organ weights and carcass measurements of gilts fed a corn-soybean meal or lysine-supplemented, corn-soybean meal diet during two different feeding regimens

Diets		Corn-soybean meal		Corn-soybean meal + lysine		P-Value[c]		
Item[b]	Feeding regimen[a]	AL	RR	AL	RR	FR	D	FR x D
Week 1								
Liver wt, lb		1.86	1.66	1.94	1.90	< .05	< .05	NS
Pancreas wt, lb		.17	.17	.15	.16	< .05	NS	NS
Tenth-rib backfat, in		.37	.40	.37	.37	NS	NS	NS
Longissimus muscle area, in^2		3.05	3.35	3.65	4.42	< .05	< .05	< .05
Hot carcass weight, lb		65.16	64.66	63.38	65.63	NS	NS	< .10
Week 2								
Liver wt, lb		1.93	1.86	1.94	2.13	< .05	NS	< .05
Pancreas wt, lb		.19	.17	.18	.21	< .10	NS	NS
Tenth-rib backfat, in		.53	.47	.50	.43	NS	NS	NS
Longissimus muscle area, in^2		4.05	3.75	4.18	4.28	NS	NS	NS
Hot carcass weight, lb		75.74	77.28	74.65	73.81	< .05	NS	< .10
Week 3								
Liver wt, lb		2.35	2.05	2.34	2.38	NS	NS	NS
Pancreas wt, lb		.19	.22	.24	.22	NS	NS	NS
Tenth-rib backfat, in		.67	.63	.63	.60	NS	NS	NS
Longissimus muscle area, in^2		3.87	4.37	4.43	4.80	NS	NS	NS
Hot carcass weight, lb		90.10	91.36	87.78	89.31	NS	NS	NS

[a]AL=ad libitum group, RR=restricted-realimentated group.
[b]FR=feeding regimen, D=diet, and NS=nonsignificant effect, P > .10.

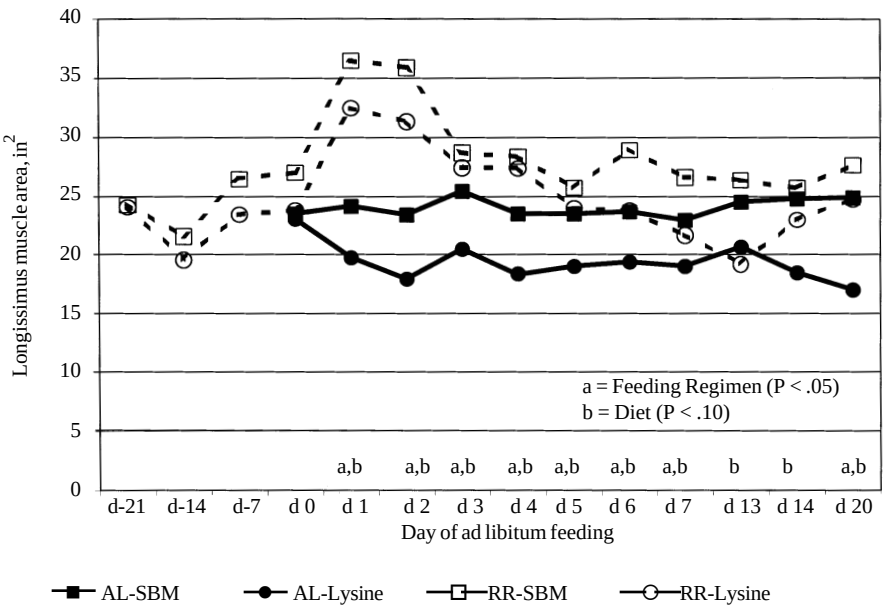

Figure 2. The response of plasma urea concentrations in gilts. Feeding treatments were ad libitum (AL) or restricted-realimentated (RR) and diet treatments were corn-soybean meal (SBM) or lysine-supplemented, corn-soybean meal (Lysine).

week 2 in the AL gilts than in the RR gilts. A feeding regimen× diet interaction (P < .05) was observed during weeks 1 and 2 of the ad libitum feeding period for hot carcass weight.

Conclusions

These results indicate that pigs do exhibit a compensatory growth response during restriction-realimentation feeding regimens. This is best illustrated by the increase in ADG during weeks 1 and 2 of the ad libitum feeding period. Plasma urea concentrations of RR gilts were much higher than those of AL gilts during days 1 and 2 of the ad libitum eating period indicating an increase in feed intake, although ADFI for the first 7 d was lower in the RR than in AL gilts. Plasma urea concentrations were consistently lower in pigs fed the lysine-supplemented diet, indicating that a two percentage unit decrease in dietary crude protein concentration is reflected in lower plasma urea concentrations. Carcass measurements showed a trend for a decrease in tenth rib BF and an increase in LMA when pigs were restricted and refed a diet with a reduction in protein concentration and supplemented with lysine. Further research is needed to explore the metabolic pathway by which pigs are able to use fat stores and deposit lean muscle tissue during a period of feed restriction and subsequent refeeding.

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The Investigation of Betaine as a Growth Promotor and/or Carcass Modifier and the Efficacy of Betaine to Replace Methionine in Finishing Diets

Steven J. Kitt
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Summary and Implications

Dietary betaine's effect on growth performance and carcass composition of finishing barrows was investigated. Two experiments were conducted to assess whether betaine improves growth and/or carcass characteristics. In the first experiment, barrows were fed either a control diet or a diet supplemented with betaine and were either crowded or not crowded. Shoulder weight was increased in pigs fed betaine. Generally, betaine had no effect on growth performance and carcass characteristics. The second experiment attempted to assess whether betaine can replace methionine in finishing diets. Betaine tended to be associated with increased fat-free lean gain. This experiment failed to show that betaine increases lean tissue deposition in situations where feed intake is decreased. Additionally, this research suggests that the current methionine recommendations may be greater than required for maximal growth. Because of the variability of responses to betaine in the literature, it is advised that betaine's efficacy and cost effectiveness be assessed on a farm-to-farm basis.

Introduction

Betaine is a byproduct of molasses production from sugar beets. During the past several years, the efficacy of betaine as a growth promotant and/or carcass modifier has been investigated. However, the conditions in which betaine improves performance and/or carcass composition have yet to be completely defined. Some researchers have shown that betaine improves growth performance in limit-fed pigs. Several management conditions are associated with reduced feed intake of growing pigs. The objective of Experiment 1 was to determine whether dietary betaine improves growth performance and/or carcass characteristics of pigs that have reduced feed intake (feed intake reduced by decreased pen space per pig). Because betaine is known to share some biological functions with methionine, the objective of Experiment 2 was to assess whether betaine can partially replace methionine in finishing pig diets.

Procedures

Experiment 1

One hundred-twenty crossbred barrows with an initial weight of 100 lb were allotted to treatments in a randomized complete block design experiment. Treatments were 0% betaine + 13 ft^2/pig (Control-UC), .125% betaine + 13 ft^2/pig (Betaine-UC), 0% betaine + 6.5 ft^2/pig (Control-C), and .125% betaine + 6.5 ft^2/pig (Betaine-C). The UC treatments had five pigs per pen, and the C treatments had 10 pigs per pen. Pigs had ad libitum access to feed and water. Pigs were housed in a mechanically ventilated building. Pigs were from lines that we characterize as having medium to high lean gain potential and were fed accordingly. Corn-soybean meal diets (Table 1) were fed in three phases. Phase 1 diets were fed from 100 to 130 lb, Phase 2 diets were fed from 130 to 190 lb, and Phase 3 diets were fed from 190 to 262 lb.

(Continued on next page)

The experiment lasted 82 days. Pigs and feeders were weighed every 14 days (denoted as periods) to determine average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (ADG/ADFI). Blood samples were collected every 14 days, and plasma was analyzed for urea concentration. Tenth-rib longissimus muscle area (LMA) and backfat depth (BF) were measured by real-time ultrasound on days 2 and 82 and used to calculate lean tissue gain (fat-free lean gain/day; FFLG; see "FFLG Calculations"). On day 82, all pigs were removed from the experiment and transported to a commercial slaughter facility. Total body electro-conductivity (TOBEC) was used to determine carcass lean percentage and primal cut weights.

Experiment 2

Sixty-four crossbred barrows with an initial body weight of 100 lb were allotted to a randomized complete block experiment. Treatments were two dietary concentrations of betaine (0 or .125%) and four concentrations of methionine (Tables 2 and 3). The diets were formulated to include one methionine deficient diet, one diet adequate (NRC requirements) in methionine, and two diets with methionine concentrations greater than NRC requirements. Pigs were individually penned, given ad libitum access to feed and water, and housed in a mechanically ventilated building.

These pigs also were characterized as being medium to high lean gain potential and were fed accordingly (Table 3), except for the methionine concentration. Diets containing corn, corn starch, feather meal, and blood meal were fed in three phases. Phase 1 was from 100 to 130 lb, Phase 2 was from 130 to 190 lb, and Phase 3 was from 190 to 247 lb (Table 2).

The trial lasted 77 days. Pigs and feeders were weighed every 14 days to determine ADG, ADFI, and ADG/ADFI. Blood samples were collected on the last day of each phase and analyzed for plasma urea concentra-

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

	Phase 1		Phase 2		Phase 3	
Ingredient	Control	Betaine	Control	Betaine	Control	Betaine
Corn	76.61	76.47	79.60	79.46	84.50	84.36
Soybean meal, 46.5% CP	20.18	20.18	17.50	17.50	12.75	12.75
Dicalcium phosphate	1.25	1.25	1.00	1.00	.85	.85
Limestone	.77	.77	.80	.80	.80	.80
L-Lysine•HCl	.10	.10	0	0	0	0
Salt	.30	.30	.30	.30	.30	.30
Vitamin premix[a]	.70	.70	.70	.70	.70	.70
Mineral premix[b]	.10	.10	.10	.10	.10	.10
BETAFIN S6→[c]	0	.14	0	.14	0	.14
Calculated Composition:						
ME[d], Mcal/lb	1.50		1.50		1.50	
Crude protein, %	15.73		14.74		12.93	
Lysine, %	.88		.73		.60	
Calcium, %	.65		.60		.55	
Phosphorus, %	.57		.51		.46	
Phosphorus, Available, %	.30		.25		.21	
Supplemental choline, ppm	77.09		77.09		77.09	
Total choline, ppm	1,102		1,048		949	

[a]Supplied per kg of diet: retinyl acetate, 3,086 IU; cholecalciferol, 386 IU; α-tocopherol acetate, 15.4 IU; menadione sodium bisulfite, 2.3 mg; riboflavin, 3.86 mg; d-pantothenic acid, 15.4 mg; niacin, 23.1 mg; choline, 77.2 mg; vitamin B_{12}, 15.0 ug.
[b]Supplied per kg of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \cdot H_2O$), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$, .02 mg; Se (as Na_2SeO_3), .3 mg.
[c]BETAFIN S6 was donated by FinnSugar BioProducts, Inc. and supplied .125% betaine in the diets.
[d]Metabolizable energy.

Table 2. Composition of experiment 2 diets, % (as-fed basis).

	Phase 1		Phase 2		Phase 3	
Ingredient	Basal	Betaine	Basal	Betaine	Basal	Betaine
Corn	67.50	67.50	67.50	67.50	66.00	66.00
Corn starch	15.51	15.37	19.29	19.15	24.20	24.06
Blood meal	3.25	3.25	1.85	1.85	.35	.35
Feather meal	7.20	7.20	5.00	5.00	3.25	3.25
Tallow	2.50	2.50	2.50	2.50	2.50	2.50
L-Lysine•HCl	.36	.36	.38	.38	.39	.39
L-Tryptophan	.06	.06	.06	.06	.07	.07
L-Threonine	.08	.08	.08	.08	.10	.10
DL-Methionine[a]	0	0	0	0	0	0
Dicalcium phosphate	1.50	1.50	1.25	1.25	1.00	1.00
Limestone	.75	.75	.80	.80	.85	.85
Salt	.30	.30	.30	.30	.30	.30
Vitamin premix[b]	.70	.70	.70	.70	.70	.70
Mineral premix[c]	.10	.10	.10	.10	.10	.10
BETAFIN S6®[d]	0	.14	0	.14	0	.14
Commercial pellet binder	.20	.20	.20	.20	.20	.20
Calculated Composition:						
ME[e], Mcal/lb.	1.54		1.56		1.59	
Crude protein, %	14.00		11.10		8.30	
Lysine, %	.85		.72		.58	
Methionine, %	.17		.15		.12	
Calcium, %	.66		.61		.57	
Phosphorus, %	.48		.43		.37	
Phosphorus, available, %	.30		.26		.21	
Supplemental choline, ppm	77.09		77.09		77.09	
Total choline, ppm	587		556		518	

[a]DL-Methionine was added at 0%, .025%, .05%, and .075% in the diets.
[b]Supplied per kg of diet: retinyl acetate, 3,086 IU/lb; cholecalciferol, 386 IU; α-tocopherol acetate, 15.4 IU; menadione sodium bisulfite, 2.30 mg; riboflavin, 3.86 mg; d-pantothenic acid, 15.4 mg; niacin, 23.1 mg; choline, 77.2 mg; vitamin B_{12}, 15.0 ug.
[c]Supplied per kg of diet: Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \cdot H_2O$), 110 mg; Mn (as MnO), 22 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$, .02 mg; Se (as Na_2SeO_3), .3 mg.
[d]BETAFIN S6 was donated by FinnSugar BioProducts, Inc. and supplied .125% betaine in the diets.
[e]Metabolizable energy.

Table 3. Comparison of methionine requirements (NRC) to experiment 2 diets on a true ileal digestible basis (% of diet).

	NRC Requirement	Phase 1 Diets			
		Methionine 1	Methionine 2	Methionine 3	Methionine 4
Lysine	.70	.75	.75	.75	.75
Methionine	.19	.15	.18	.20	.23
Methionine + cystine	.41	.50	.53	.55	.58
Tryptophan	.13	.16	.16	.16	.16
Threonine	.45	.53	.53	.53	.53
	NRC Requirement	Phase 2 Diets			
		Methionine 1	Methionine 2	Methionine 3	Methionine 4
Lysine	.58	.64	.64	.64	.64
Methionine	.16	.13	.16	.18	.21
Methionine + cystine	.34	.42	.44	.47	.49
Tryptophan	.11	.13	.13	.13	.13
Threonine	.38	.43	.43	.43	.43
	NRC Requirement	Phase 3 Diets			
		Methionine 1	Methionine 2	Methionine 3	Methionine 4
Lysine	.48	.52	.52	.52	.52
Methionine	.13	.11	.13	.16	.18
Methionine + cystine	.29	.34	.36	.39	.41
Tryptophan	.09	.12	.12	.12	.12
Threonine	.32	.36	.36	.36	.36

Table 4. Effects of dietary betaine and crowding on growth performance, carcass characteristics, and plasma urea concentration (Experiment 1).

	Treatment				Space	Diet	Space× Diet
	Control UC[a]	Betaine UC[a]	Control C[a]	Betaine C[a]	P-value		
Period I (day 1-14)							
ADG[b], lb	2.20	2.15	1.92	1.97	<.005	NS	NS
ADFI, lb	5.26	5.03	4.69	4.90	<.05	NS	<.10
ADG/ADFI		.42	.43	.41	.40	<.10	NS
PU, mg/100 mL	30.05	29.61	30.26	32.63	<.05	NS	<.10
Period II (day 15-28)							
ADG, lb	2.22	2.09	1.98	1.91	<.005	<.10	NS
ADFI, lb	6.22	6.04	5.78	5.78	<.10	NS	NS
ADG/ADFI	.36	.35	.34	.33	<.05	<.10	NS
PU, mg/100 mL	33.69	33.45	33.82	31.14	NS	NS	NS
Period III (day 29-42)							
ADG, lb	2.06	2.06	1.82	1.92	<.001	NS	NS
ADFI, lb	6.30	6.36	5.88	5.84	<.001	NS	NS
ADG/ADFI	.33	.33	.31	.33	<.10	<.10	<.05
PU, mg/100 mL	35.33	35.23	34.15	34.00	NS	NS	NS
Period IV (day 43-56)							
ADG, lb	1.89	1.89	1.73	1.88	NS	NS	NS
ADFI, lb	6.96	6.93	6.25	6.66	<.05	NS	NS
ADG/ADFI	.27	.27	.28	.28	NS	NS	NS
PU, mg/100 mL	31.26	29.53	30.34	31.08	NS	NS	NS
Period V (day 57-70)							
ADG, lb	1.74	1.87	1.62	1.63	<.005	NS	NS
ADFI, lb	7.41	7.25	6.56	6.80	<.05	NS	NS
ADG/ADFI	.24	.26	.25	.24	NS	NS	NS
PU, mg/100 mL	32.56	30.72	32.65	31.20	NS	NS	NS
Period VI (day 71-82)							
ADG, lb	2.10	2.02	1.61	1.85	<.01	NS	NS
ADFI, lb	7.69	7.45	6.25	6.89	<.05	NS	NS
ADG/ADFI	.28	.27	.26	.27	NS	NS	NS
Overall (day 0-82)							
ADG, lb	2.03	2.01	1.78	1.86	<.001	NS	NS
ADFI, lb	6.64	6.51	5.90	6.14	<.005	NS	NS
ADG/ADFI	.31	.31	.30	.30	NS	NS	NS
FFLG, lb	.71	.69	.61	.64	<.001	NS	NS
Ham wt., lb	21.17	21.65	20.32	20.56	NS	NS	NS
Longissimus wt., lb	26.04	25.97	24.83	25.44	NS	NS	NS
Shoulder wt., lb	26.42	26.64	25.92	26.19	<.10	<.05	NS
Total lean wt., lb	96.22	94.54	85.97	89.68	NS	NS	NS

[a]Control UC: Control diet + 13 ft^2/pig; Betaine UC: Betaine supplemented diet + 13 ft^2/pig; Control C: Control diet + 6.5 ft^2/pig; Betaine C: Betaine supplemented diet + 6.5 ft^2/pig.
[b]ADG=average daily gain; ADFI=average daily feed intake; PU=plasma urea concentration; FFLG=fat-free lean gain.

tion. Tenth-rib LMA and BF were measured by real-time ultrasound on days 1 and 77, and used to calculate FFLG. On day 77 all pigs were removed from the experiment.

FFLG Calculations

Note: Different equations (Eq. 1) were used for Experiment 1 and 2 because hot carcass weight were not obtained for Experiment 2.]

Eq. 1) **(Experiment 1)**
.95 [7.231 + (.437 . hot carcass wt., lb) - (18.746 . 10th rib BF depth, in.) + (3.877 . 10th rib LMA, $in.^2$)]

Eq. 1) **(Experiment 2)**
.95 [3.95 + (.308 . live wt., lb) - (16.44 . 10th rib BF depth, in.) + (4.693 . 10th rib LMA, $in.^2$)]

Eq. 2) **(Experiment 1 and 2)**
.95[(.418 . liveweight, lb.) - 3.65]

FFLG (lb/day) = (Equation 1-Equation 2)/Duration of the experiment

Results and Discussion

Experiment 1

Crowding decreased (P < .01) ADG for Periods I, II, III, V, and VI (Table 4). The control diet and the diet supplemented with betaine did not affect ADG throughout the experiment. However, in Period II, a trend (P < .10) for improved ADG resulted for pigs fed the control diet. Crowded pigs had reduced (P < .001) ADG throughout the entire experiment. Crowding decreased ADFI in all periods (P < .10) of the experiment and the overall (P < .005) experimental period. Feed intake was not affected by dietary treatment. However, there was a trend (P < .10) for crowded pigs fed betaine to consume more feed than pigs fed the control diet and crowded during Period I. Increased (P < .10) ADG/ADFI was observed in uncrowded versus crowded pigs in Period I. In Period II, ADG/ADFI was improved (P < .05) in uncrowded pigs versus crowded pigs, and tended (P < .10) to be improved in pigs fed the control diet versus the betaine-supplemented diet. In Period III, ADG/ADFI was improved (P < .05) in crowded pigs fed betaine, whereas

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Table 5. Effects of dietary betaine and methionine concentrations on growth performance, carcass characteristics, and plasma urea concentration (Experiment 2).

	Methionine 1		Methionine 2		Methionine 3		Methionine 4		Betaine	Methionine	Betaine× Methionine	Linear	Quadratic
	CON[a]	BET[b]	CON	BET	CON	BET	CON	BET	P-value				
Phase I													
ADG[c], lb	2.02	1.92	1.68	1.77	2.08	1.82	1.58	1.84	NS	<.05	<.10	<.10	NS
ADFI, lb	5.53	5.45	5.21	5.03	5.76	5.74	5.08	5.51	NS	<.05	NS	NS	NS
ADG/ADFI	.37	.35	.32	.35	.36	.32	.31	.34	NS	<.10	<.05	<.05	NS
PU, mg/100 mL	24.61	22.91	20.73	22.13	25.77	23.17	24.28	24.16	NS	NS	NS	NS	NS
Phase II													
ADG, lb	1.96	2.26	2.21	2.22	2.16	2.27	2.00	2.10		NS	NS	NS	NS
ADFI, lb	6.41	6.69	6.76	6.84	6.58	6.99	6.20	6.32	NS	NS	NS	NS	NS
ADG/ADFI	.31	.34	.33	.33	.33	.33	.32	.33	NS	NS	NS	NS	NS
PU, mg/100 mL	22.93	18.17	21.04	21.69	21.80	21.47	21.21	21.61	NS	NS	NS	NS	NS
Phase III													
ADG, lb	1.71	1.93	1.73	1.91	1.92	1.66	1.70	1.69	NS	NS	NS	NS	NS
ADFI, lb	6.22	6.51	6.10	6.74	6.69	6.07	6.40	6.46	NS	NS	NS	NS	NS
ADG/ADFI	.27	.30	.28	.29	.29	.28	.27	.26	NS	NS	NS	NS	NS
PU, mg/100 mL	17.71	14.40	14.75	16.08	18.86	15.42	15.95	13.73	NS	NS	NS	NS	
Overall													
ADG, lb	1.86	2.03	1.88	1.97	2.03	1.89	1.77	1.85	NS	NS	NS	NS	NS
ADFI, lb	5.91	6.25	5.94	6.40	6.31	6.15	5.90	6.00	NS	NS	NS	NS	NS
ADG/ADFI	.32	.33	.32	.31	.32	.31	.30	.31	NS	NS	NS	NS	NS
FFLG, lb	.61	.66	.58	.62	.63	.61	.56	.60	<.10	NS	NS	NS	NS
LMA, in.^{2}	5.95	6.04	5.65	5.86	5.93	5.74	5.46	6.01	NS	NS	NS	NS	NS
BF, in.	.96	.90	1.01	.98	1.08	.96	.94	.96	NS	NS	NS	NS	NS

[a]CON: Control diet (no betaine).
[b]BET: Betaine supplemented diet.
[c]ADG=average daily gain; ADFI=average daily feed intake; PU=plasma urea concentration; FFLG=fat-free lean gain.

the uncrowded pigs consuming the control diet had greater ADG/ADFI. However, overall ADG/ADFI was not affected by diet or space allocation. Plasma urea concentration was increased (P < .05) in crowded pigs during Period I. Diet or space allocation did not affect plasma urea concentration in the other periods or for the overall experimental period. Longissimus muscle weight, ham weight, and total pounds of lean were not affected by diet or space allocation. Shoulder weight was increased (P < .05) in pigs fed betaine and tended (P < .10) to be increased in uncrowded pigs. Fat-free lean gain was greater (P < .01) in uncrowded versus crowded pigs but no difference was observed in FFLG between pigs fed control and betaine-supplemented diets.

Experiment 2

In Phase I, increasing the methionine concentration in the diets linearly decreased (P < .05) ADG (Table 5). Plasma urea concentration, ADFI, and ADG/ADFI were not consistently affected by dietary methionine concentration or betaine. Longissimuss muscle area and BF were not affected by methionine concentration or betaine supplementation. Lean gain was increased (P < .10) in pigs fed betaine versus the pigs fed the control diet. Because the concentrations of dietary methionine used in this study appear to be above the requirement, the relationship between betaine and methionine could not be adequately evaluated.

Conclusions

Other recent data suggest that FFLG is improved by betaine supplementation when feed/energy intake is below normal; however, Experiment 1 did not show similar results. The efficacy and/or economic advantage of betaine should be analyzed in each production system. Additionally, this report suggests that the methionine requirement (estimated for pigs with similar lean growth potential and produced under similar management conditions) may be lower than current NRC recommendations for finishing pigs.

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Effect of Wean-to-Finish Management on Pig Performance

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Summary and Implications

An experiment consisting of three trials was conducted to determine the effect of wean-to-finish management systems on pig performance. Treatments consisted of: 1) wean-to-finish single stock (WF) at 7.5 ft²/pig from weaning (17 day mean age) to slaughter in a fully slatted finishing facility; 2) double stock (DS) at 3.75 ft²/pig for eight weeks following weaning and then split into two pens at 7.5 ft²/pig each; and 3) nursery (NF) at 3.75 ft²/pig for eight weeks in a conventional nursery followed by movement to the finisher and stocked at 7.5 ft²/pig to slaughter. All pens had one two-hole wean-finish dry feeder per 15 pigs and one cup-drinker per 15 pigs. While there were health related performance problems in Trials 1 and 2 due to PRRS, there were no trial by treatment interactions. At the end of eight weeks, WF pigs were heavier (P<.01) than DS pigs with NF pigs intermediate in weight (63.1, 59.2, and 60.9 lbs, respectively). The heavier weight was due to a difference (P<.01) in feed intake between the WF and DS treatments. There was no effect of nursery phase treatment on feed efficiency. There was no effect (P>.1) of any management treatment on any grow-finish phase production parameter reported. These data suggest that the performance improvement associated with wean–to-finish production systems occurs during the first eight weeks postweaning. They also suggest that the response can be expected even when health challenges occur in a production system.

Introduction

Designing production systems for pig flow used to be relatively simple. Following weaning, pigs were moved to a nursery for four to eight weeks and then moved to a grower-finisher facility. The nursery was designed for pigs from 10 to 45 pounds and the grower-finisher was for pigs from 45 pounds to slaughter. Engineers, farm managers and consultants all had experiences with these facilities. They knew what the temperature requirements and associated heating costs were, what stocking density gave the best pig performance and economic return, and how much manure was produced per facility each year.

The advent of wean-to-finish facility management has changed many producers' thoughts regarding facility needs and pig flow considerations. Instead of designing nurseries for six to eight groups of pigs per year (turns) and finishers for 2.7 to 2.8 turns per year, wean-to-finish facilities are designed for 2.1 turns per year. Instead of having one nursery and two finishers as the ideal planning combination, we now are concerned about pairing up wean-to-finish facilities having 2.1 turns per year with finishers having 2.7 turns per year. Producers, engineers and their advisers are asking questions about stocking strategies to maximize performance and economic return, manure production values for environmental regulators, heating systems, feeder selection and a host of related questions.

While the popular press has carried numerous reports of producer experiences with wean-finish facilities, there have been no published studies designed to compare the effects of common management systems on weaned pig performance to slaughter.

Materials and Methods

This research investigated the effects of three weaned pig management systems on performance from weaning to slaughter. The systems were:

1) Wean-to-finish (WF). Pigs were weaned into fully slatted finishing pens stocked at 7.5 ft²/pig from weaning to slaughter.
2) Double stock (DS). Pigs were weaned into fully slatted finishing pens at 2x the density of WF (3.75 ft²/pig). Eight weeks after weaning, the pigs were randomly divided into two groups, with one group remaining in the same pen and the other relocated to another pen in the same facility. Pigs then were grown to slaughter at 7.5 ft²/pig.
3) Nursery moved to finisher (NF). Pigs were weaned into a nursery and stocked at 3.75 ft²/pig. Eight weeks after weaning, they were relocated to the same finisher as WF and DS and grown to slaughter at 7.5 ft²/pig.

The growing-finishing facility used in this research is located at the University of Nebraska's Haskell Ag

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Laboratory near Concord, Neb. It is a five-year-old double wide, naturally ventilated, fully slatted facility with 8 foot x 14 foot pens. The cement slats are 7 inches wide with a 1 inch slot.

The nursery was mechanically ventilated with unvented heaters. Pens with 5 ga woven wire flooring measured 8 feet x 8 feet with a gate inserted in one corner to restrict usable pen area to 56.25 ft^2. Minimum winter ventilation was provided by a single speed fan exhausting from the manure storage area under the decks. Because of reduced pig density in this experiment, the minimum ventilation was 6.7 CFM/pig.

There were 15 pigs per pen for the WF and NF treatments and 30 pigs per pen for the DS. Pen size was not adjusted in the event of pig death. There was a two-hole wean-finish feeder and one bowl-drinker for every 15 pigs. Heat lamps were used as the supplemental heat source for the WF and DS treatments. Comfort mats were used in all treatments and pigs were floor fed 3X daily for the first week after weaning.

A commercially available nursery diet sequence was used. Diets were switched during the eight-week nursery phase based on a preplanned feed budget to 40 lbs body weight. Corn-soybean meal based diets in meal form containing 2% added fat were formulated to contain 1.1% lysine from 40 to 55 lbs, 1.0% lysine from 55 to 80 lbs, .88% lysine from 80 to 130 lbs, .73% lysine from 130 to 190 lbs, and .60% lysine from 190 lbs to slaughter.

Temperatures in the nursery were maintained at 84 to 86°F the first week after weaning and were programmed to decline 3 to 4 F° per week thereafter until 70°F. However, two of the three trials began in April and by mid-May the planned reduction in temperature could not be accomplished because of higher outside air temperatures. Air temperature in the finishing facility was maintained at 73 to 76°F with heat lamps used for supplemental heat as necessary. Heat lamps were removed after three to five weeks, depending on the need for supplemental heat.

Pigs were weaned at 17 days of age and transported to the research unit at weaning. In Trials 1 and 2, the pigs were purchased from a source 100 miles away, and in Trial 3 they were from a source 70 miles away. Pigs were barrow offspring of PIC genetic crosses. Trials were started in April and October in an attempt to pair up heating seasons and minimize any effects of season due to large variations in heating expenses.

Results and Discussion

In Trials 1 and 2, gut edema was diagnosed by attending veterinarians on weeks two through four following weaning. It was most severe in the WF and DS treatments. In Trial 1, only the WF and DS treatments received medication while in Trial 2, all pigs were medicated. There was no evidence of gut edema in Trial 3.

The diagnosis of gut edema coincided with an increase in messy pens. For the first four to six weeks after weaning, the pigs walked "with" the cement slat and dunged on top of the slat. They then tracked this material throughout the pen with tracking reaching its peak about four weeks after weaning. The only dry area in the pen was directly under the heat lamp vs the nursery treatment with woven wire flooring which had no tracking of manure. Based on gross observations, it appeared that there were increased humidity and ammonia levels due to this tracking in the WF/DS facility.

Pigs in Trials 1 and 2 had many health challenges due to complications associated with PRRS, while in Trial 3, no such complications were evident. However, there was no trial by treatment interaction for pig performance during the nursery phase, suggesting that health status of the pigs was not a factor in the response to wean-to-finish management during the nursery phase.

In spite of the health problems noted for Trials 1 and 2 and the differential treatment of gut edema, WF pigs performed better than DS and NF pigs during the nursery phase (Table 1). The response appears to be due to greater feed intake, resulting in faster daily gain, with no difference in feed conversion. Even though temperatures in the nursery were set on the low end of the thermoneutral zone to limit the possibility of heat stress during the nursery phase, feed intake was lower for the NF vs WF treatments.

The reduction in performance for DS vs WF is probably related to group size. In the range of group sizes used in this experiment, there is good evidence that increasing group sizes results in a decrease in daily feed intake and daily gain. However, the reduction in individual pig performance doesn't outweigh the overall improvement in pig weight gain per unit of floor space, a critical factor when assessing the economics of various wean-to-finish strategies.

Many would argue that the NF treatment allocated too much space per pig compared to conventional nurseries which are typically stocked at no more than 3 ft^2 per pig. This space allocation was chosen to: 1) match the allocation of the DS treatment, and 2) provide sufficient space so there would be a minimal chance that space restriction during the nursery phase would negatively affect performance. It's quite possible that many of the reports in the popular press of improved performance for wean-to-finish are due to nursery facility limitations. These limitations involve inadequate space, improper feeder design for the heavier pigs now common in nurseries, improper temperature sequencing, etc. The NF treatment was designed to remove these limitations if possible.

Wean-to-finish treatments did not affect performance during the growing-finishing phase (Table 2). Average daily gain was similar for WF, double stocked pigs that remained in the same pen (DSS), double stocked pigs that were moved to new pens (DSM) and NF pigs. Treatment also did not affect variation in weight within a pen as judged by the within pen coefficient of variation of weight when the first pig from the pen was marketed. There was also no effect of treat-

Table 1. Impact of wean-to-finish regimens on weaned pig performance during the nursery phase.

	Regimen[a]			Contrasts	
Item	WF	DS	NF	WF vs NF	WF vs DS
No. pens	12	12	12		
Weaning wt, lb	11.2	11.2	11.2	NS[b]	NS
56 day wt, lb	63.1	59.2	60.9	NS	<.01
CV 56 day wt %[c]	14.6	17.0	14.7	NS	NS
Average daily gain, lb	.92	.86	.89	NS	<.01
Average daily feed, lb	1.53	1.42	1.47	<.1	<.01
Feed:Gain	1.66	1.66	1.64	NS	NS

[a]WF - wean-to finish; DS - Double stock; NF - Nursery.
[b]NS - Not significant (P>.1).
[c]Coefficient of variation of within pen weight.

Table 2. Impact of wean-to-finish regimens on pig performance during the finishing phase.

	Regimen[a]				Contrasts		
Item	WF	DSS	DSM	NF	DSM vs DSS	WF vs NF	WF vs DSS+DSM
No. pens	12	12	12	12			
Weight when first pig sold[b]	224.8	217.3	220.5	220.7	NS[c]	NS	<.05
CV market weight, %[d]	9.3	11.3	10.4	10.5	NS	NS	NS
Average daily gain, lb	1.88	1.88	1.85	1.85	NS	NS	NS
Average daily feed, lb	4.91	4.82	4.88	4.88	NS	NS	NS
Feed:Gain	2.61	2.61	2.60	2.64	NS	NS	NS

[a]WF - wean-to finish; DSS - Double stock stay in same pen; DSM - Double stock moved to new pen; NF - Nursery moved to finisher.
[b]Average pen weight when first pig removed for slaughter at 240 lbs or greater.
[c]NS - Not significant (P>.1).
[d]Coefficient of variation of within pen weight when first pig removed for slaughter.

ment on daily feed intake or feed conversion efficiency.

The four-pound advantage at 56 days for NF vs DS (Table 1) translated into a 2+ day advantage to market since there was no difference between treatments in daily gain during the grow-finish period. With weekly weighings and a numeric, but non-significant reduction in weight variation within a pen, WF pigs were 5.9 pounds heavier than the average of both DS and NF treatments when the first pig weighting 240 pounds or greater was removed for slaughter.

Conclusion

These results support the reports in the farm press of improved performance for pigs housed in wean-to-finish management systems. Feed intake during the nursery phase was elevated for wean-to-finish housed pigs, resulting in faster daily gains during the eight-week nursery period. The lack of trial by treatment interactions suggests that the response is not influenced by the health status of the pigs during the nursery period. These results will be used in a production system model to examine the economics of wean-to-finish production systems versus conventional systems with nurseries and grow-finish facilities.

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Acylation Stimulating Protein: A Potential Regulator of Fat Synthesis

Jess Miner
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Sheila Jacobi[1]

Summary and Implications

The long term goal of this project is to understand the molecular mechanisms controlling fat synthesis. These experiments indicate that acylation stimulating protein (ASP) can stimulate the incorporation of fatty acids into lipid in cultured adipose tissue. This finding justifies a future effort to determine if manipulation of ASP can modify fat deposition.

Introduction

Several hormones are known to influence fat accretion by stimulating the mobilization of fat stores. Growth hormone (PST), beta adrenergic agonists, and certain steroids have this effect. Application of this knowledge may someday allow swine producers to reduce backfat in these pigs. However, in certain situations it may be advantageous to enhance fat accretion. For example, intramuscular fat contributes to meat juiciness and flavor, and perhaps to tenderness. If a hormone which stimulates fat accretion could be identified, pork quality may be improved by: 1) enhancing intramuscular fat content; or 2) reducing deposition of fat in undesirable depots.

Acylation stimulating protein (ASP) was identified by Canadian researchers who were studying the development of fat cells in obese people (Cianflone et al., 1989). They found that ASP can stimulate fat cells to synthesize and store fat. Their reports then prompted our interest in whether ASP regulates fat synthesis in the pig. We initially determined that pigs do express a gene which codes for ASP. The objective of the current research was to determine if ASP purified from human blood (hASP) can stimulate fat synthesis in porcine adipose tissue.

Materials and Methods

Experiment 1

The objective of the first experiment was to determine if hASP could enhance fat synthesis in cultured porcine adipose tissue. Eight barrows ranging in weight from 210 to 270 lb (four Whiteline and four Genepool) were transported from the UNL swine facility at Mead to Lincoln and housed in individual pens. Pigs had ad libitum access to a corn-soybean meal diet containing 14% crude protein except as indicated in Experiment 2. A sample of subcutaneous adipose tissue was surgically obtained from each pig during anesthesia. The inner layer of each sample was cut into 15-mg sections and incubated in multi-well plates in buffered nutrient media containing radioactive oleate at 39° C for 2 hr. During this incubation, tissue sections from each pig were exposed to 0, .1, 1, or 10 micromolar doses of hASP. Following the incubation, fat synthesis was determined by assaying the incorporation of radioactive oleate into extractable lipid.

Experiment 2

The objective of this experiment was to determine whether the sensitivity of porcine adipose tissue to hASP is influenced by energy status of the pig. The eight barrows described above were allocated into two groups; each group was composed of two Whiteline and two Genepool pigs. One group had ad libitum access to feed and the other group was restricted to 1.2 lb/day (~50% of maintenance energy requirement). After 3 wk, adipose tissue samples were obtained and cultured as described for Experiment 1. During the following 3 wk, the feeding regimen was reversed and adipose tissue samples were again obtained and cultured.

Results and Discussion

The results of Experiment 1 are presented in Figure 1. Fat synthesis in adipose tissue was enhanced by hASP ($P < .10$). Incorporation of oleate was 20% greater in tissue exposed to the high dose of hASP than in the control. We interpret this result to mean that ASP can promote fat synthesis. The response of 20% which we observed, however, is less than the response observed by others in human fat cells. Perhaps ASP derived from pigs would have been more effective than human ASP. Thus far we do not have purified porcine ASP.

In Experiment 2 we hypothesized that fat cells that are actively synthesizing lipid may differ in sensitivity to hASP compared to fat cells derived from energy-restricted pigs. In this experiment, the pigs gained 48.5 lb during the 3-wk-period of ad libitum

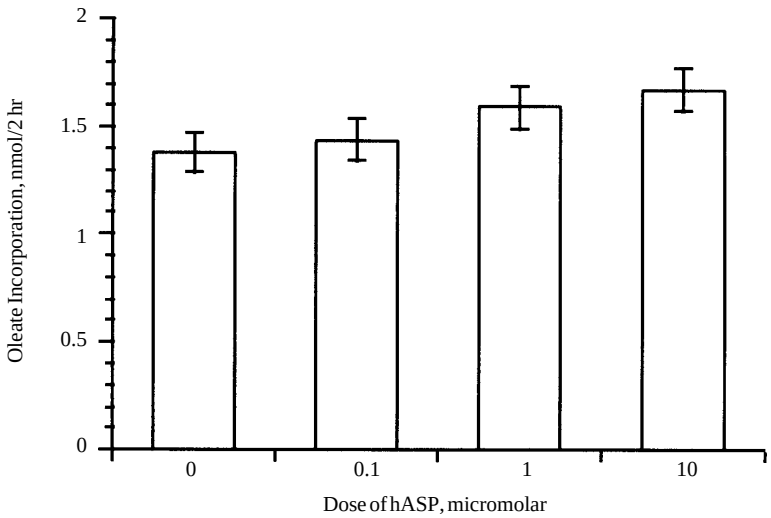

Figure 1. Oleate incorporation into total extractable lipid of adipose tissue cultured in presence of four concentrations of hASP (Experiment 1). Error bars represent SEM. Main effect of ASP (P < .10).

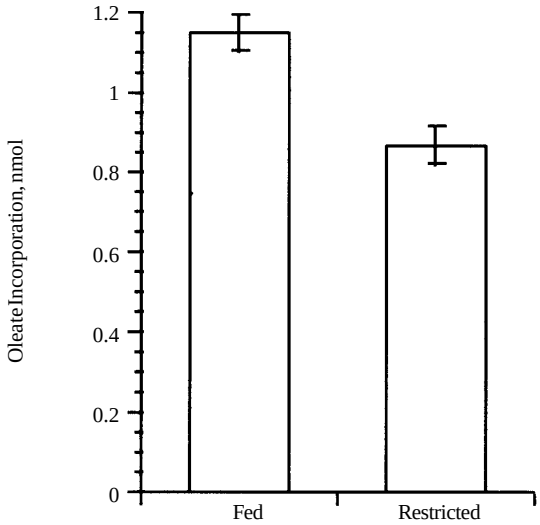

Figure 2. Oleate incorporation into total extractable lipid of adipose tissue derived from feed-restricted and ad libitum feeding pigs (Experiment 2). Main effect of diet (P < .01).

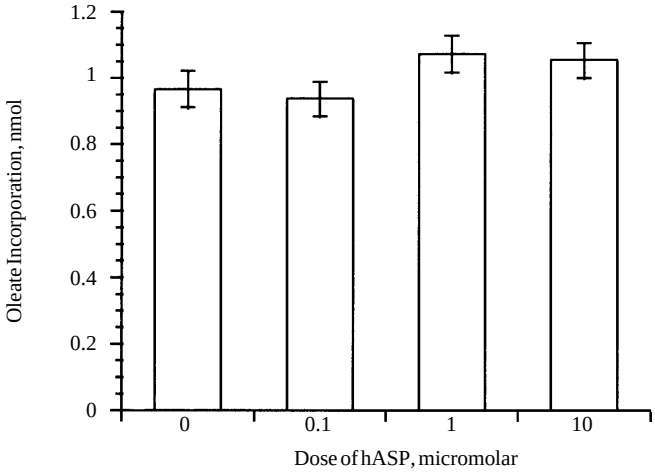

Figure 3. Oleate incorporation into total extractable lipid of adipose tissue cultured in presence of four concentrations of hASP (Experiment 2). Error bars represent SEM. Main effect of ASP (P < .01). ASP by Diet interaction (P > .50).

feeding, and lost 4.3 lb during the 3 wk that intake was restricted to 50% of predicted maintenance energy requirement. The rate of fat synthesis was reduced 24% in samples obtained from feed-restricted pigs as compared to pigs with unrestricted feed intake (P < .01; Figure 2). In contrast to our hypothesis, however, the effect of hASP was not influenced by feed intake (P > .5). Human ASP increased oleate incorporation by about 10% regardless of whether the tissue sample was derived from feed-restricted pigs or pigs that had ad libitum access to feed (P < .10; Figure 3).

The results of this research support the hypothesis that ASP is a hormonal regulator of fat synthesis in pigs. In two experiments, we observed a stimulation of oleate incorporation into lipid in cultured adipose tissue due to hASP exposure. The effect we observed was not as strong as that reported for human fat cells, and we have not demonstrated that pigs produce ASP protein. However, we have found that pigs produce mRNA from an ASP gene and we have used a clone of this mRNA to produce small amounts of porcine ASP protein. We are currently making an antibody to this protein and hope to purify ASP from porcine blood with this antibody.

Our ultimate goal is to find ways to improve pork production efficiency and(or) pork product quality. It may be possible to accomplish this by manipulating fat accretion by altering the effect of ASP in specific tissues. However, it is too early to determine if it will be practical to modify ASP or its effects. Regardless of whether ASP can be manipulated to improve pork production, learning about its mechanism adds to our overall understanding of pig biology which will ultimately lead to applications for pork producers.

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[1]Carin Ramsel was an undergraduate research assistant and is currently enrolled in Kansas State University Veterinary College. Sheila Jacobi was a graduate research assistant and is currently employed by Ohio State University. Jess Miner is an assistant professor in animal science. This project was funded by the National Pork Producers Council on behalf of the Nebraska Pork Producers Association.

Duration of PRRS Virus Infections and Proportion of Persistently Infected Pigs

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J.-H. Sur
F.A. Osorio[1]

Summary and Implications

The objective of this study was to more fully characterize persistent PRRSV infections in swine. Twenty-eight 35-day-old segregated-early-weaned pigs were inoculated intranasally with PRRSV. Serum and tonsil biopsy samples were collected on days 0, 7, 14, 28, and then about monthly thereafter until day 251 post inoculation (PI). Virus was isolated from serum and tonsil biopsy samples through days 28 and 56 PI, respectively. Viral RNA was detected in serum and tonsil biopsy samples by RT-PCR through day 251 PI, although no positive serum samples were detected on days 84-196 PI. Greater proportions of day 28 and 56 PI serum samples and tonsil biopsies were found to be PRRSV RNA positive by RT-PCR than positive by virus isolation. Although 20 of 28 tonsil biopsies collected on day 84 PI were positive by RT-PCR, only one of 28 tonsil biopsies collected one month later (day 119 PI) was positive. Three pigs returned to seronegative status on or after day 196 PI. Neither virus nor viral RNA was detected in these animals beyond day 119 PI. Conversely, five pigs that were persistently infected through day 225 or 251 PI remained seropositive throughout the study although one pig had an ELISA S/P ratio of 0.41, nearly at the cutoff point of 0.40. The results confirm RT-PCR is more sensitive than virus isolation in identifying PRRSV-infected pigs. The abrupt drop in the proportion of pigs with RT-PCR positive tonsil samples from day 84 to day 119 PI indicates most pigs clear the virus within three to four months, but some may remain persistently infected for several months.

Introduction

Porcine reproductive and respiratory syndrome virus (PRRSV) causes a potentially devastating disease in swine herds. Understanding the transmission of PRRSV is paramount to developing successful prevention programs. Research has documented transmission between pigs in direct contact and allowed investigation of how long pigs remain infectious. Early transmission studies demonstrated pigs were persistently infected and capable of transmitting virus for at least two to three months after initial inoculation. Field observations of herds infected for long periods of time and transmission via purchase of clinically normal, but PRRSV-infected, animals highlights the importance of characterizing the persistency of PRRSV infection.

The proportion of persistently infected animals also directly affects the dynamics of virus transmission within a herd. Since a persistently infected animal is a potential source of infection, the ability to estimate the proportion of persistently infected animals is of critical importance in developing prevention and control programs. Producers often are faced with the decision of whether to introduce previously infected animals into their herds. Currently, it is not clear if pigs that have returned to seronegative status following initial seroconversion are capable of still harboring PRRSV.

The objective of this study was to more fully characterize persistent PRRSV infections in swine. In particular, the study assessed what proportion of inoculated animals become persistently infected with PRRSV. The serological status of persistently infected pigs also was investigated.

Materials and Methods

Thirty-five segregated early-weaned pigs were obtained from a herd known to be free from PRRSV infection. At 35 days of age, the pigs were randomly assigned to one of five isolation rooms. The pigs in four of the rooms were designated as principals and were inoculated intranasally with PRRSV. The pigs in the fifth group were designated negative controls and

Table 1. Detection of PRRSV from serum and tonsil samples.

	Virus Isolation		RT-PCR	
DPI*	Serum†	Tonsil	Serum‡	Tonsil
7	28/28	26/28	27/28	27/28
14	20/28	23/28	28/28	28/28
28	2/28	9/28	7/28	27/28
56	0/28	4/28	1/28	21/28
84	0/28	0/28	0/28	20/28
119	NT	0/28	0/28	1/28
147	NT	0/28	0/28	2/28
168	NT	0/28	0/28	0/28
196	NT	0/28	0/28	0/28
225	NT	0/28	1/28	1/28
251#	NT	0/28	1/28	2/28

*Days post inoculation.
†Number of serum or tonsil biopsy samples from which PRRSV was isolated/number tested.
‡Number of serum or tonsil biopsy samples positive for PRRSV RNA /number tested by RT-PCR.
#Necropsy samples.
NTNot Tested.

Table 2. RT-PCR results of pigs in which viral RNA was detected on day 119 PI or beyond

	Days Postinoculation								
Pig	28	56	84	119	147	168	196	225	251
1	T							T	
2	T	T	T		T				
16	T	T	T		T				
24	S,T		T						T
26	S,T	T	T						T
29	T		T						S
34	T		T	T					
40	T	T						S	

S Viral RNA detected in serum sample by RT-PCR
T Viral RNA detected in tonsil sample by RT-PCR

were not inoculated with virus.

Samples were collected on days 0, 7, 14, 28, and then about monthly thereafter until day 251 post inoculation (PI). After collecting blood samples, the pigs were anesthetized so that tonsil biopsies could be taken. A dermatology biopsy punch was used to harvest approximately 4mm x 8mm section of tissue from each palatine tonsil.

Virus isolation on MARC 145 cells was conducted on serum and tonsilar biopsy samples collected from the principals and a randomly selected negative control pig for a given collection day. Virus isolation was conducted on serum collected on days 7-84 PI and on tonsil homogenates prepared from biopsies or necropsy tissues collected on days 7-251 PI. Serum samples and an aliquot of each tonsil homogenate from days 7-251 PI also were analyzed by Reverse Transcriptase - Polymerase Chain Reaction (RT-PCR). RT-PCR was done using a Gene Amp EZ r Tth RNA PCR Kit (Perkin Elmer, Branchburg, NJ). Serum antibody levels were assessed by ELISA (IDEXX Laboratories, Westbrook, ME) on all serum samples.

Results and Discussion

Virus isolation and RT-PCR results are summarized in Table 1. The results confirm RT-PCR is more sensitive than virus isolation in identifying PRRSV-infected pigs. Positive RT-PCR results do not necessarily indicate the presence of viable virus, only the presence of viral RNA. At the same time, it appears likely that in order for the viral RNA to be detected out to day 251 PI, replicating virus also must be present for extended periods of time. This was supported by concurrent research in which bio-assay pigs seroconverted after inoculation with tissue samples collected from pigs inoculated five months previously. Additional research is needed to better determine the duration of time during which pigs remain contagious to susceptible pigs.

As seen in Table 2, the detection of viral RNA by RT-PCR from day 119 to 251 PI was sporadic in that although viral RNA was detected in eight animals during this time, RNA was not detected from the same pig during consecutive months. Furthermore, viral RNA was not detected from both serum and tonsil samples collected on the same day from a pig. The sporadic detection of viral RNA in serum after months of negative samples has been reported previously. Although it is possible that the observation of sporadic positive samples is due to false positive reactions, samples from the seven negative control pigs were consistently negative with one exception. That single exception occurred on day 7, which logically is a time at which a large percentage of samples are positive creating an increased chance of cross contamination. The fact that neither this pig nor other control pigs in direct contact with it developed a serological response enhances the certainty that this was a false positive reaction. Other than that, all of the negative controls remained negative. No other false positive reactions were apparent throughout the rest of the experiment.

Of particular interest is the abrupt drop in the proportion of pigs with RT-PCR positive tonsil samples from day 84 to day 119 PI. These results corroborate earlier work in which PRRS virus was isolated from tonsil scrapings from three of four pigs collected on day 84 PI, but at most, one out of four pigs on subsequent samples. The results demonstrate that although pigs can remain persistently infected for several months, this is a fairly infrequent event, with most pigs clearing the virus between three and four months. Our experiment does not rule out — in fact, it may suggest — that very low levels of replication may continue

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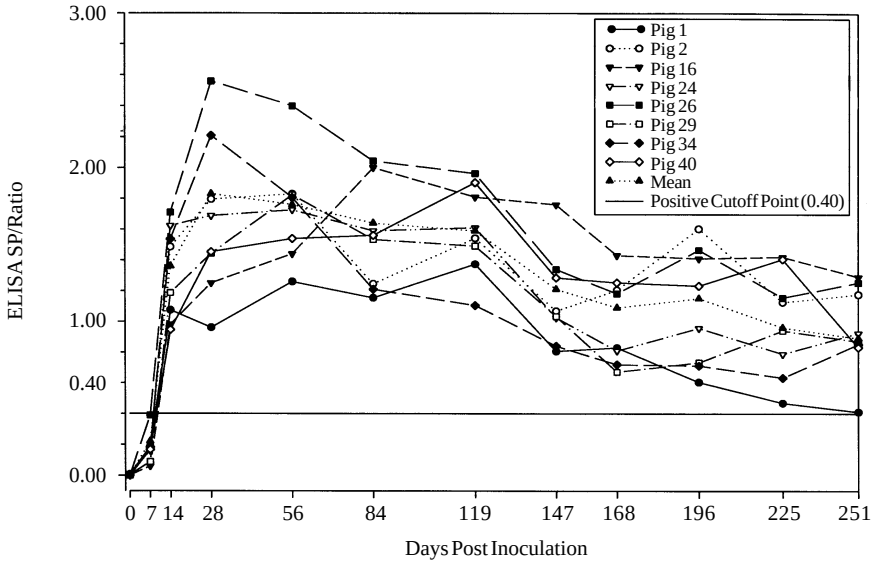

Figure 1. ELISA S/P ratios of persistently infected pigs.

allowing sporadic detection of viral RNA.

All inoculated animals seroconverted. Three pigs returned to seronegative status (ELISA S/P ratios less than 0.40) on or after day 196 PI. Virus was not isolated nor viral RNA detected in these animals beyond day 119 PI. As shown in Figure 1, the eight pigs that were persistently infected for 119 days or more according to RT-PCR results did not return to seronegative status by the end of the trial although the S/P of Pig 1 was 0.41 on day 251 PI. This pig was positive up to day 28 PI by virus isolation and days 28 and 225 PI by RT-PCR of the aliquot of the virus isolation preparation. With the exception of Pig 1 the results suggest that an animal that has returned to seronegative status is unlikely to harbor the virus. The results of Pig 1 suggest that viral RNA may still be detected in pigs with an S/P less than or at least near the cutoff point. This finding has significant impact on the use of the ELISA test in the identification of PRRSV infected animals.

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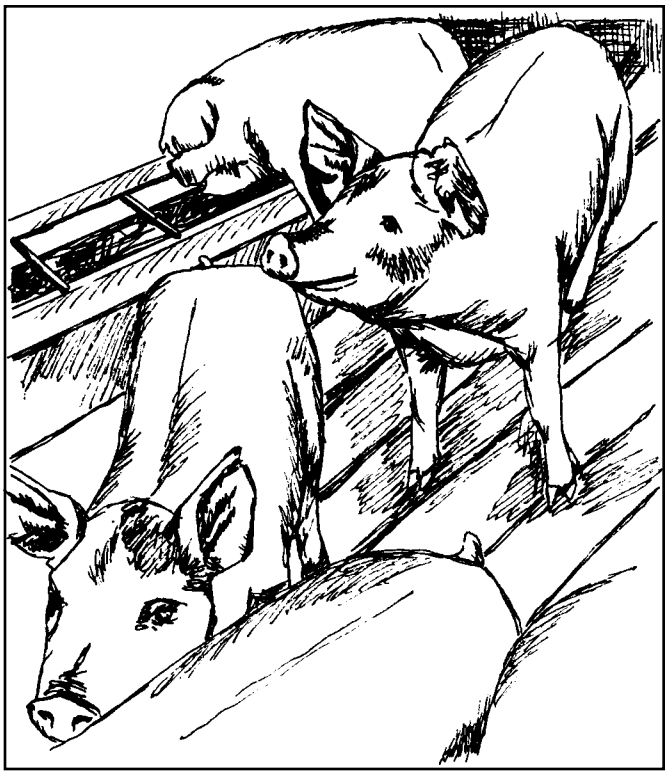
[1]R.W. Wills is assistant professor of veterinary and biomedical sciences, A.R. Doster is professor of veterinary and biomedical sciences, J. Galeota is a laboratory supervisor in veterinary and biomedical sciences, J.-H. Sur was a post-doc in veterinary and biomedical sciences, and F.A. Osorio is professor of veterinary and biomedical sciences.

Acknowledgements

The authors thank Blaine Clowser, Jennifer Friesen, Eric Mousel, Andrea McCormic and Rossana Allende for their technical assistance.

This research was partially funded by the Nebraska Pork Producers Association and the National Pork Producers Council in association with the National Pork Board. This research was also supported by USDA National Research Initiative Competitive Grant Program Project Number 96-3520-3678.



Nebraska Competitive Livestock Marketing Act

J. David Aiken[1]

LB835, the Nebraska Competitive Livestock Marketing Act, was adopted in 1999. The act regulates marketing and livestock ownership for packers slaughtering 150,000 or more animal units per year (150,000 steers, 350,000 calves up to 450 pounds, or 750,000 hogs). The act regulates packer livestock ownership, hog and cattle purchases and contracts, and livestock price reporting. The restrictions differ between hog and cattle purchases, but the price-reporting requirements are the same in both cases. Price-reporting requirements go into effect Feb. 15, 2000. There is some disagreement regarding when other provisions of the act take effect. LB835 took effect May 27, 1999. A copy of the law is available from your county extension office. Ask for publication NF99-401.

Legislative findings. The act is intended to provide livestock price transparency by establishing livestock price and contract reporting requirements, eliminating volume premiums and volume-based incentives and reinforcing Initiative 300's prohibition of packer feeding.

Packer livestock ownership. Effective May 27, 1999, packers cannot directly or indirectly own or feed livestock except for five days incidental to slaughter. Packers (if incorporated) have also been prohibited since November 1982 from owning livestock or agricultural land under article 8 §12 of the Nebraska constitution (popularly known as Initiative 300). Violations are prosecuted by the Nebraska Attorney General, and violations are punished by a fine of at least $1,000 per day.

Hog purchases. Packers may not purchase hogs on terms that are not available to other livestock sellers. However, prices may vary throughout a marketing period. It is unclear whether this provision took effect May 27, 1999 or goes into effect when the reporting requirements take effect, Feb. 15, 2000.

An exception is made for direct, spot or cash purchases where any price differential is based on carcass merit or transportation costs, and prices are reported (including the price differential and its reason). A second exception is for contracts to purchase hogs at a specific date or time if the requirements for cash sales are met and if the contract is offered to other sellers. These provisions would appear not to take effect until the price reporting requirements go into effect, Feb. 15, 2000.

The hog purchase restrictions may be enforced by private litigation if the person bringing the lawsuit can prove that he or she has been damaged by the violation. The hog seller also may cancel a contract violating these requirements. Packer violation of these requirements is a class IV misdemeanor, punishable by a $500 fine per violation.

Hog price reporting. Beginning Feb. 15, 2000, packers must report all prices paid for hogs twice daily to the Nebraska Department of Agriculture and the USDA Ag Marketing Service. Reports must include (1) cash prices and number of hogs purchased, (2) base price and quality premiums or discounts, (3) formula pricing, and (4) contract prices and formulas. Seller names are not reported. NDA must report prices to the public. Packers violating price reporting requirements are punishable by a fine of up to $1,000 per day. Deliberate false reporting is a class IV misdemeanor ($100-$500 fine per violation). The attorney general or any person harmed by price reporting violations (e.g. livestock producers) may file suit to enforce them.

Cattle purchase contracts. Packer contracts to purchase cattle for slaughter cannot require the seller to keep the price secret and must specify a delivery date. Formula or grid pricing is illegal unless a base price is specified prior to the cattle being committed or scheduled for slaughter. It is unclear whether these provisions took effect May 27, 1999 or go into effect when the reporting requirements take effect, Feb. 15, 2000.

Contracts specifying a delivery month allowing the packer to specify the week or delivery are exempted where the packer reports the contract price and delivery date. This provision would appear not to take effect until the price reporting requirements go into effect, Feb. 15, 2000.

The cattle purchase restrictions may be enforced by private litigation if the person bringing the lawsuit can prove that he or she has been damaged by the violation. The cattle seller may also cancel a contract violating these requirements. Finally, packer violation of these requirements is a class IV misdemeanor, punishable by a $500 fine per violation.

Fees. NDA may charge up to 2 cents per animal unit to cover program investigation and enforcement.

Enforcement. NDA must report violations to the attorney general, who is responsible for enforcement. Livestock sellers economically harmed by violations may also sue privately to enforce the act. If you have questions regarding the act, contact the Nebraska attorney general at (402) 471-3839 or the Nebraska Department of Agriculture at (402) 471-2341.

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District Court Rules in Progress Pig Case

J. David Aiken[1]

Article 8 §12 of the Nebraska Constitution (popularly referred to as Initiative 300) establishes several requirements for corporations to legally qualify as family farm or ranch corporations in Nebraska. Under one requirement, a majority of the family farm or ranch corporation's shareholders must be family members, "at least one of whom is a person residing on or actively engaged in the day to day labor and management of the farm or ranch." On Sept. 16, 1998, Otoe County District Court Judge Ronald Reagan ruled in *Hall v. Progress Pig* that where no family member resides on the farm or ranch, a family member must perform agricultural production labor on a *daily* basis on the farm or ranch in order for a corporation to legally qualify as a family farm or ranch corporation. The decision has significant implications for swine production in Nebraska, as many swine operations are organized and operated similarly to Progress Pig Inc., as family farm or ranch corporations.

Progress Pig Inc. is an Otoe county hog operation, with David Zahn as the sole shareholder. Mr. Zahn, who lives off the farm, handles finance and marketing and works with production consultants. However Mr. Zahn's production manager feeds and cares for the pigs, not Mr. Zahn. Judge Reagan concluded that Mr. Zahn did provide labor and management for the farming operation. However, the judge ruled that Mr. Zahn's labor was insufficient to qualify as the *daily* labor and management required by article 8 §12. Judge Reagan stated

"It is my opinion that the drafters of this Initiative intended that the words 'day to day' be directed to the particular [agricultural] product involved. 'Day to day' labor in this context must be seen as respecting the output or product of the farm. When the product is pigs or cattle, the expectation is that one would need to be involved on an everyday basis. If the product were grain, for example, 'day to day' [labor] would encompass the various stages of [planting], fertilizing, and harvesting, which might not have to be addressed on an everyday basis."

The judge noted that daily labor requirements would vary depending on whether the farming operation were a crop operation or a livestock operation. The judge concluded that spending a few days per week on the farm and little time directly caring for the livestock did not satisfy the article 8 §12 daily labor and management requirement.

Judge Reagan further noted that Zahn was an absentee landowner and that in the 1997 *Pig Pro* decision, the Nebraska Supreme Court stated that absentee ownership and operation of farm and ranch land by a corporate entity is precisely what article 8 §12 prohibits.

The case has been appealed to the Nebraska Supreme Court. If the Supreme Court approves the Otoe county court decision, Mr. Zahn will have under article 8 §12 two years within which to (1) make the farm his principal residence, (2) reorganize the farm as a sole proprietorship or a general partnership, (3) provide daily labor and management for the swine operation, (4) discontinue the farming operation, or (5) sell the property. If he does not implement one of these options within two years, the farm would become the property of the state of Nebraska. Mr. Zahn would lose the legal advantage of limited liability if the farm were operated as a proprietorship or general partnership.

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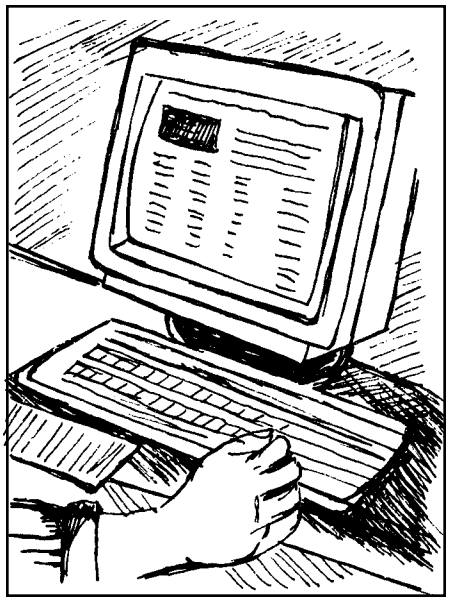
Explanation of Statistics Used in This Report

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 percent 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. Bear in mind, if the experimenter obtained this result in each of 100 experiments, 5 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. With that figure, the chance that random



sampling caused observed treatment differences is less than 1 in 100. Evidence for real treatment differences, then, 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 for real treatment differences to exist when the value of P is between .05 and .10. "Tendency" is used because we are not as confident the 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 percent 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 percent chance that random differences between pigs on the treatments caused the observed response.