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

Historical Materials from University of Nebraska-Lincoln Extension

Extension

2005

# 2005 Nebraska Swine Report

Duane E. Reese

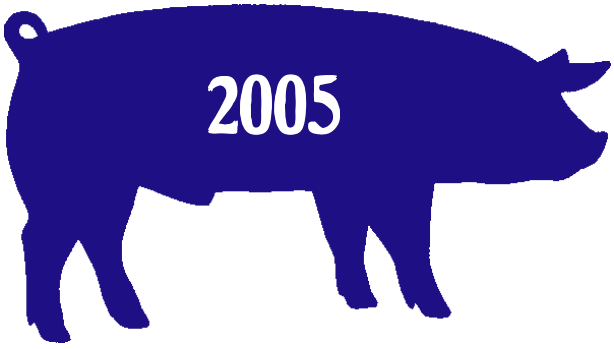
Follow this and additional works at: https://digitalcommons.unl.edu/extensionhist

Part of the Agriculture Commons, and the Curriculum and Instruction Commons

Reese, Duane E., "2005 Nebraska Swine Report" (2005). *Historical Materials from University of Nebraska-Lincoln Extension*. 32.
https://digitalcommons.unl.edu/extensionhist/32

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

University of Nebraska Cooperative Extension EC 05-219-A




# NEBRASKA SWINE REPORT

- Nutrition
- Genetics
- Housing
- Management
- Health
- Meats

Web site:
www.ianr.unl.edu/pubs/swine/pigpdf.htm

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, Dean and Director of Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources.

University of Nebraska Cooperative Extension educational programs abide with the non-discrimination policies of the University of Nebraska-Lincoln and the United States Department of Agriculture.

## Table of Contents

**Health**
PRRSV Negative Herds: A Survival Analysis ..... 3

**Production Management**
Shoulder Ulcers in Sows ..... 6
Out-of-Feed Events in Grow-Finish Pigs: Causes and Consequences ..... 9
Teeth Clipping — Have You Tried to Quit? ..... 12

**Nutrition**
Research Proposal Summary: Effects of Nutrition During Gilt Development on Sow Lifetime Productivity of Two Prolific Maternal Lines ..... 14
Effect of Increasing Dietary Crude Protein Concentration on Growth Performance and Serum Insulin-Like Growth Factor-I Concentration in Barrows and Gilts ..... 16
Development of a NCR-42 Vitamin-Trace Mineral Mix ..... 21

**Genetics**
Incidence and Inheritance of Splayleg in Nebraska Litter Size Selection Lines ..... 24

**Business Management**
How Big is "Big Enough" to Make a Living in Pork Production? ..... 28

**Housing**
Heating Systems for Wean-to-Finish Facilities ..... 31

**Meats**
Rapid Methods to Predict Lean Quality Attributes in Pork ..... 36
Does Insulin and Leucine Stimulate Muscle Protein Synthesis? ..... 40

**Appendix**
Explanation of Statistics Used in This Report ..... 45

Issued January 2005, 1,900

**Nebraska Swine Report Acknowledgments for 2005**

Alpharma, Inc, Ft. Lee, NJ
BASF Corp. Mt. Olive, NJ
Boehinger Ingelheim Vetmedica, St. Joseph, MO
Cooperative Extension Division, University of NE, Lincoln, NE
Danbred NA, Inc., Dorchester, NE
Elanco Animal Health, Indianapolis, IN
Farmland Foods, Crete, NE
Hormel Foods, LLC, Austin, MN
Tyson Foods, Madison, NE
Monsanto Company, St. Louis, MO
National Pork Board, Des Moines, IA
Nebraska Agricultural Research Division, University of NE, Lincoln, NE
Nebraska Pork Producers Association, Lincoln, NE
Sioux Preme Packing Co., Sioux Center, IA
U.S. Meat Animal Research Center, Clay Center, NE
Waldo Farms, Inc., DeWitt, NE

**Cover Photo:**
Darryl Barnhill checks pigs in the farrowing area at the ARDC Swine Unit. ***Photo by Duane Reese***

*The 2005 Nebraska Swine Report was compiled by Duane Reese, Extension Swine Specialist, Department of Animal Science.*

**2005 Nebraska Swine Report**

**Editor:** Dan Moser
**Typesetting & Design:** Anne Moore

# PRRSV Negative Herds: A Survival Analysis

**Locke A. Karriker**
**Ruby Destajo**[1]

**Summary and Implications**

*Despite a significant body of research, interventions for PRRSV infection remain elusive. Traditional approaches to managing the risk of diseases have not been successful in many cases of PRRSV infection. While elimination of the virus from farms is possible, it is not without cost and re-infection is common. This survey sought to quantify the expected duration of PRRSV negative status on farms that were repopulated with PRRSV negative animals or had undergone a PRRSV elimination program. Results of 96 cases reveals a range of <1 to 312+ weeks duration of negative status. A survival analysis of 84 farms revealed a probability of surviving with negative status for two full years of 58.3% with a standard error of 11.5%. The probability of survival through 4 years was 42% with a standard error of 16%. A greater percentage of farms that were re-infected shared resources such as equipment, personnel, and/or vehicles with known positive farms. Positive farms also had a relatively shorter average distance to known positive farms than those remaining negative. The results of this study indicate that PRRSV-negative farms are not very likely to remain negative for a long duration given current technologies. Longer survival of negative status appears to be associated with greater distance from known positive farms and stricter biosecurity. Sharing of equipment and other resources as well as a closer distance to other farms should be considered risk factors that can lessen the probability of farms maintaining negative status.*

**Introduction**

Porcine Reproductive and Respiratory Syndrome Virus (PRRSV) remains a constraint to productivity and profitability in swine herds world-wide, costing about $228 to $302 per female in the breeding herd and about $6.25 to $15.25 per pig in the growing herd according to Iowa State University research. While an extensive body of research over the past decade has characterized the virus, the pathological lesions associated with infection, interactions with other disease etiologies, and eventually led to the development of diagnostic tests for both the virus and antibodies to it, control in and among swine herds remains elusive.

Elimination of the virus from swine herds has proven to be a challenging task and has increasingly been the focus of discussions surrounding the topic of PRRSV management and interventions in the herd. Some of the reasons for its persistence in the herd pertain to what is known or commonly accepted about the behavior of the virus in individual animals:

1) Boars can shed virus in semen intermittently for extended periods of time with few or no clinical signs.
2) Persistently infected animals exist and can shed to naïve contacts.
3) The immune response in the pig is poorly understood and/or variable given different contexts.

Other reasons pertain to established facts about viral behavior in populations:

1) PRRSV subpopulations exist in endemic breeding herds.
2) Multiple genetically diverse PRRSV strains can coexist on farms simultaneously.
3) Vertical and horizontal transmission of PRRSV occurs by many known routes and potentially by additional unknown routes.
4) Infection can occur in utero and produce piglets that are viremic at birth
5) The introduction of negative gilts to positive farms, or gilts that have been exposed to a genetically diverse strain of PRRSV can lead to sustained PRRSV circulation on farms.
6) Vaccine efficacy is highly variable depending on vaccine type (killed versus modified live virus), genetic relatedness of the vaccine virus and wild type, and timing of vaccination relative to exposure.

Because successful, profitable production requires successful risk management, increasingly formal

*(Continued on next page)*

risk analysis methods are being applied to swine health. One formal definition of risk was presented by Iowa State University in 2003:

Risk = Pr(event)*consequence
Where:
Pr = probability
Event = the defined hazard

Therefore, to reduce risk, it is necessary to reduce the probability of disease and/or reduce its consequences. Speaking of disease in general, probability reducers include: biosecurity, uni-directional pig flow, shower-in / shower-out, traffic and visitor control, eliminating employee contact with other swine herds and rodent control. Historical approaches to reducing the consequence of disease include: adequate nutrition, appropriate ventilation, vaccination, acceptable stocking densities, water quality and availability, and reduction of stressors.

In the context of "financial loss (or cost) due to PRRSV" as the hazard, reviewing what is already known and generally accepted about PRRSV yields few opportunities to reduce the probability or consequences of clinical PRRSV infection on farms. Most of the typical reducers of consequence have been shown to have little or no impact on the cost of PRRSV. Additionally, farms that have virus circulating would be considered at high probability for clinical signs in animals and therefore have a high risk of cost due to PRRSV. This has led to consideration of PRRSV negative status as an opportunity to greatly reduce the probability of cost due to PRRSV on farms.

Several PRRSV strategies have been outlined to eliminate virus from positive farms. The most common methods are 1) total depopulation/repopulation, 2) "rollover" scenarios where positive farms take advantage of a decline or stop in circulation and switch to introduction of negative replacements, 3) herd closure, and 4) test with removal. These strategies have several common elements including the necessity to stabilize immunity (through depopulation, natural circulation over time, or forced exposure/acclimation) and reduce the risk of new virus exposure. Farms that are populated with naïve animals initially also share the latter risk. It is unrealistic to expect negative farms to remain negative indefinitely because:

1) There are costs associated with the various elimination strategies,
2) Many anecdotal experiences have been described for farms that have been infected or re-infected despite significant biosecurity interventions,
3) Biosecurity interventions incur costs,
4) Existing facility location and design have been identified as risk factors and are not easily changed, especially in light of the political regulatory climate.

As discussed here and elsewhere, the costs of PRRSV (and therefore, the expected improvement in animal performance upon elimination) have been estimated. With the addition of information on the likely duration of negative status, the financial return can be estimated. Thus, a preliminary survey was conducted to quantify the expected duration of PRRSV-negative status on farms that were repopulated with PRRSV negative animals or had undergone a PRRSV elimination program.

**Methods**

The survey was conducted in October and November, 2003 among 45 selected swine veterinary practitioners who are American Association of Swine Veterinarians members. Selection criteria included their experience in handling PRRSV-negative farms and /or whether they have initiated elimination of the virus from positive herds.

**Results**

Responses were received from 39 veterinarians, an 86% response rate. Forty-six percent of the veterinarians who responded had PRRSV elimination projects occurring on 96 farms.

A majority of the farms serviced by participating veterinarians were farrow-to-wean (63%). About half of those (31%) were farrow-to-finish. Twenty-three percent of the farms (n = 22) inventoried 1,000 or fewer females, about 37% of the farms (n = 36) inventoried 1,000 to 2,000 females, 21% of the farms (n = 20) had 2,000 to 3,000 females, and 19% of farms (n = 18) had more than 3,000 females.

Although the reasons that motivate swine practitioners to strive to eliminate PRRSV are interrelated, most of the respondents indicated a need to eliminate the virus to be able to provide negative replacements (81%) for their current stock. Others were primarily motivated to improve the farm's commercial (17%) and genetic performance (10%). Some did it for other purposes like research and *Actinobacillus pleuropneumonia* depopulation (8%). About 17% of the respondents cited multiple reasons for beginning an elimination effort.

Of the methods of elimination discussed above, 44% of the respondents incorporated herd closure as a technique, wherein introduction of replacement stock was suspended for a defined period of time and subsequently a new naïve batch was introduced. Nearly 40% opted for complete depopulation of the farm and subsequent repopulation with naïve

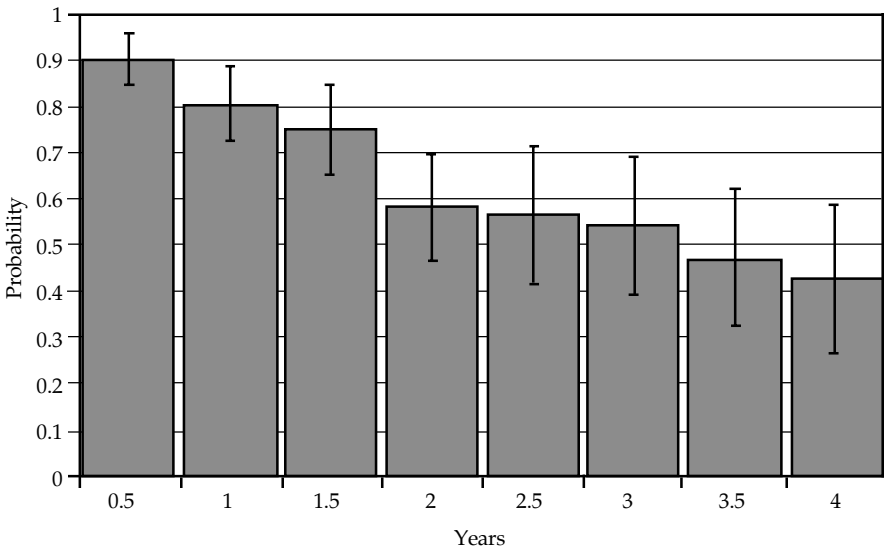



**Figure 1. Probability of survival through time period — all farms (N = 84).**

animals after thorough cleaning. Only 1% followed the test-and-removal method in eliminating the identified positives from the herd. Some (27%) used a combination of the known methods while 26% were not satisfied with these methods and tested other means not mentioned in the list.

The respondents were asked about the week and year of recent clinical PRRSV occurrence prior to elimination to establish the timing of original break and the week and year of completion of the elimination action to establish the timing of the elimination action. Completion of an elimination activity was arbitrarily defined as the date when the first PRRSV naïve animal farrowed. If the farm was subsequently infected, they were asked about the week and year of the first clinical PRRSV infection after the completion of the previous elimination action to establish the timing of subsequent reinfection. Initial PRRSV infection, elimination and reinfection had to be confirmed with diagnostic testing.

Eighty-four of the farms serviced by the respondents were included in the survival analysis. There were 48 farms that had remained negative for PRRSV at the time of the survey. The remaining 36 farms experienced subsequent reinfection (rebreaks). The period of survivorship was defined as that period from the time of completed elimination action to the date of survey (for negative farms) or to the time of rebreak (for positive farms). Survivorship curves and standard errors were estimated for 1) all farms, 2) farms that used depopulation-repopulation method, and 3) farms that used herd-closure technique. No significant differences were found between the curves. Survival analysis of all farms resulted in a decreasing probability of remaining PRRSV-negative with time (Figure 1).

When asked about the causes for PRRSV rebreaks, 36% of the veterinarians who responded indicated they had no explanation. About 31% believed area spread, including lateral spread by insects was believed to be the culprit. Infected replacement stocks including transmission through semen and infected gilts were reasons cited by 22% of the respondents. Eleven percent blamed the cause for reinfection on the equipment being used in the farm (11%). A greater percentage of positive (40%) than negative farms (12.5%) shared resources with a known positive farm. As expected, the average distance of a positive farm to a known PRRSV-positive farm was shorter than that of a negative farm (5.38 miles for positives; 15.15 miles for negatives).

Swine practitioners were also encouraged to give their comments about PRRSV. One of the problems encountered with remaining PRRSV negative is farm location, according to some respondents. The area around the farm became highly populated with swine sometime after the farm was built. Another problem mentioned was that the farm's isolation facility was located too close to the sow farm to prevent infection of incoming gilts. Some complained of positive pigs located within half a mile of the farm. There were those who suspected transport transmission but could not verify it because no similar PRRSV isolates were identified in the nearby area. Others obtained PRRSV viral isolates that were more closely related to the neighbor's farm than historical isolates from the home farm.

While a good starting point, the results of this preliminary survey are limited because of bias in recall or in targeting farms, small sample size, in the classification of strategies, in definitions, and in the setting of an arbitrary starting point. To further understand the issue, it is recommended a prospective study and a thorough epidemiologic investigation of breaks be performed.

---

[1]Locke Karriker and Ruby Destajo are veterinarians in the Veterinary Diagnostic and Production Animal Medicine Department at Iowa State University. References are available from the authors at karriker@iastate.edu. This paper was made possible by the contribution of numerous practitioners who donated the time necessary to compile and summarize their experiences. We sincerely appreciate their willingness to share that information and time.

# Shoulder Ulcers in Sows

**Duane E. Reese**
**Barbara E. Straw**
**Jess M. Waddell**[1]

**Summary and Implications**

*A literature review was conducted on shoulder ulcers in sows. Shoulder ulcers are caused by pressure that the shoulder blade exerts against tissues that overlie it. Those issues lose blood supply and die. Because the pressure is directed outward, tissue damage occurs before the ulcer is evident on the skin surface. Ulcer prevalence is highly variable; 0 to more than 20% of the sows in 218 herds evaluated had shoulder ulcers. Ulcers usually develop during late gestation and early lactation and many heal shortly after weaning. Numerous risk factors for developing shoulder ulcers have been identified. Inactivity and thin sow body condition seem to be the most important ulcer risk factors. Thus, farrowing caretakers may be able to prevent ulcers by carefully monitoring each sow's lying behavior and attempting to fix any problem that restricts movement. Checking the gestation and lactation feeding programs to ensure that sows enter the farrowing area in proper body condition also may prevent ulcers. Experience from Denmark indicates a pad fixed to the shoulder of sows at the first sign of redness in the skin may prevent ulcers too. Sows starting to develop an ulcer benefit from treatment of underlying issues that cause inactivity, daily application of a topical disinfectant, early weaning and movement to a hospital pen, or a rubber mat to lie on in the farrowing crate. Close observation and appropriate care of sows especially around the time of farrowing should keep the incidence of shoulder ulcers low in the pork industry.*

**Introduction**

Shoulder ulcers or pressure sores in sows are becoming an important issue in Denmark. Danish slaughterhouses recently begin pressuring pork producers to reduce the number of sows delivered to their plants that have or have had shoulder ulcers. Shoulder ulcers may be an indication of sow welfare. Moreover, it is possible that these sores may cause sows to change positions frequently in the crate to alleviate pain, thus increasing the chances of crushing piglets, according to Iowa State University researchers. Danish scientists suggest it's possible that open shoulder ulcers predispose the sow to septicemia or blood poisoning. The purpose of this paper is to examine why shoulder ulcers develop and what producers can do about them.

*Anatomy of the Shoulder*

The shoulder blade or scapula has a ridge (spine) running its length that is the highest part of the bone (Figure 1). In some sows this spine is more pronounced than in others. When the sow lies on her side the bulk of her weight presses down on her shoulder. Because it sticks out the farthest, the spine of the scapula bears the most weight. The pressure actually comes from the weight of the sow that presses downward, resting on the point of the spine of the scapula, much like the weight is concentrated while wearing high heels. Continual pressure on the tissues overlying the scapula restricts their blood supply and eventually without blood, these tissues die. Because the nerves that supply the area also lose their blood supply and die, the condition is probably not painful.

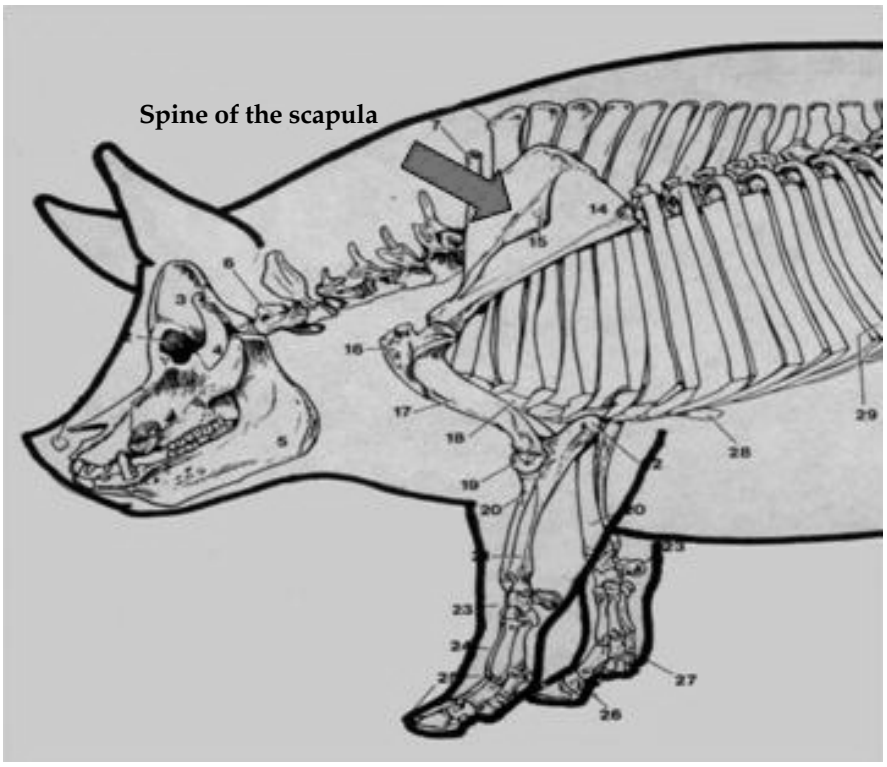



**Figure 1. Anatomy of the shoulder of a sow.**

**Figure 2. Shoulder ulcer on a sow.**

Because the direction of the pressure is from inside out, most of the damage to the underlying tissue already has been done before it finally progresses to the skin (Figure 2).

*Prevalence and timing of ulcer development*

The prevalence of shoulder ulcers in sows has been reported by three groups of researchers. In 1996 North Carolina researchers found 8.3% of the 1,916 females of breeding age they examined in a farrow-to-wean operation had shoulder ulcers. In 2004 researchers in Denmark examined 570 lactating sows in 10 commercial herds and reported 12% of the sows had shoulder ulcers. In a second Danish study involving 23, 794 sows from 207 sow herds, about 70 herds reported only 5 percent or fewer of their sows had shoulder ulcers while in about 15 herds there were 20% or more of the sows with shoulder ulcers. These results demonstrate that significant variation in ulcer prevalence exists in the pork industry. The variation is likely related to differences in production facilities and management strategies.

The North Carolina researchers determined that ulcer prevalence was strongly associated with time after farrowing. A year later those researchers monitored late-gestation sows and gilts that did not have shoulder ulcers on day 0 (when they were moved into farrowing crates), and on days 5, 12, 18, 40, 54 and 68 thereafter. Ulcers were observed on 33 of 206 shoulders (16%) by day 5. The highest incidence of ulcers was observed on day 12 (99 out of 206 shoulders; 48%). All the ulcers had healed by day 68, although marked healing was observed between day 12 and 18 while the sows were still in the crates.

These results indicate that shoulder ulcers develop rapidly in early lactation and they can begin to heal rapidly. Sows do lie on their side a considerable amount of time during parturition so it makes sense most shoulder ulcers would develop during early lactation. In a previous study about half of the sows did not shift the side they were lying on while they farrowed. Perhaps these sows are most likely to develop shoulder ulcers.

*Risk factors associated with ulcers*

The North Carolina scientists used sow body condition, parity, date of farrowing and litter size born data in their analysis to determine risk factors for shoulder ulcers. In one Danish study sows were examined visually for body condition, hoof length, leg disorders and skin integrity. The overall cleanliness of the farrowing area and sow parity and lying-down behavior also were assessed. In the second Danish study a total of 33 potential risk factors related to facilities and management strategies were evaluated. From these three studies a list of key risk factors can be compiled:

- Prolonged recumbency or lying during parturition
- Reduced activity in late gestation and early lactation
- Post-farrowing illness
- Sow body condition — thin sows have a greater ulcer risk
- Sow body weight — heavier sows have a higher ulcer risk
- Parity — ulcer prevalence increases with increased parity
- Moist skin — increases ulcer prevalence
- Duration of farrowing
- Source of replacement gilts — using one's own replacement gilts decreased ulcer prevalence
- Hospital or sick pen — use decreased ulcer prevalence
- Type of sow housing — confinement (stalled and tethered or tethered) increased ulcer prevalence
- Number of caretakers in farrowing area — increased ulcer prevalence was observed with two caretakers compared to one

This list demonstrates shoulder ulcers in sows is a multifactorial condition. That is, there are many factors that interact to contribute to the condition, making ulcer prevention difficult.

*Treatment and care*

Sows starting to develop shoulder ulcers should be closely examined to determine if there

*(Continued on next page)*

are any other problems that keep them from moving around. If a sow has a sore foot, if the floor provides poor traction or if the sow is too large to easily stand in the crate, these conditions should be attended to so that they don't contribute to the sow's inactivity. A topical disinfectant such as povidone iodine solution or wound dressing should be applied to the ulcer daily. If possible, wean the sow early and move her to a hospital pen to allow the ulcer to heal more rapidly.

In general it is not necessary to administer injectable antibiotics to sows with shoulder ulcers that appear dry or "meaty" as shown in Figure 3. If the ulcer contains pus or if the sow runs a fever or goes off feed, an antibiotic, usually penicillin, should be given in addition to applying a topical disinfectant and trying to correct the reasons that the sow is lying down so much. After weaning the sow will take better care of herself and not spend so much time lying on her side and irritating the ulcer. If the sow cannot be weaned for a while, place a rubber mat in the farrowing crate to help distribute the pressure on the sow's shoulder. Lay the mat on the floor so that when the sow is lying down her shoulders are on it.

**Figure 3. A meaty or dry shoulder ulcer in a sow.**

**Figure 4. Shoulder pad fixed to a sow in Denmark.**

### Prevention

Studies indicate that many risk factors are involved in the development of shoulder ulcers in sows. Some factors are not easy to address. It's clear that lack of animal movement especially during late gestation and early lactation is an important factor in development of shoulder ulcers. Thus, it seems important for caretakers to carefully monitor each sow's lying behavior and attempt to fix any problem that restricts her movement. Also, it might be useful to get sows up soon after they have finished farrowing to relieve pressure on the tissues in the shoulder. Sows that appear stained or that have indentations of the flooring design on one side probably have been lying on that side for some time. Providing these sows a rubber mat to lie on probably will prevent an ulcer from developing.

Ulcer risk is also higher in thin sows so it is reasonable to reevaluate the sow feeding program during gestation and lactation in an attempt to reduce the number of thin sows that enter the farrowing area. Don't overfeed sows in gestation, because too much weight gain will cause

sows to be too heavy at farrowing and therefore increase the risk of shoulder ulcers.

If shoulder ulcers occur more frequently during the summer and drip cooling is being used in farrowing, perhaps repositioning the coolers over the sows' heads or reducing the drip rate might be useful in reducing ulcer risk.

Some producers in Denmark are using a "Skulderpude" (shoulder pad) to help prevent shoulder ulcers (Figure 4). The pad is strapped very firmly to the shoulder of the sow using nylon straps and Velcro. Thus, it is out of her reach and piglets can't destroy it. It has foam padding on the inside and a thick canvass material on the exterior.

Producers are installing the pads on sows as soon they observe any redness of the skin on the shoulder. The pads appear to be relieving some of the pressure that is placed against tissues overlying the scapula and preventing further damage. They fit so tightly to the shoulder that it is not advised to place them over an open sore. Pads usually remain on until sows are weaned. Then they are washed and reused.

[1]Duane E. Reese is an Extension Swine Specialist in the Department of Animal Sciences at the University of Nebraska. Barbara E. Straw is an Extension Veterinarian in the Department of Large Animal Clinical Sciences at Michigan State University. Jess M. Waddell is an undergraduate student in the Department of Animal Science at Oklahoma State University. References are available at dreese1@unl.edu by request.

# Out-of-Feed Events in Grow-Finish Pigs: Causes and Consequences

**Mike Brumm**
**Brian Richert**
**Jeremy Marchant-Forde**
**Ruth Marchant-Forde[1]**

**Summary and Implications**

*In theory, bulk bins and automated feed delivery systems assure an uninterrupted flow of feed to the feeder in swine grow-finish facilities. In practice, growing-finishing pigs have varying disruptions in feed availability, some of which may have serious consequences. While every swine grow-finish facility has occasional disruptions due to mechanical failures in the feed delivery system, there are additional disruptions due to human errors associated with keeping feed in the bulk bin and feed bridging associated with feed removal from the bin. Out-of-feed events are a known cause of ulcers in pigs and are suspected of being associated with increased incidence of hemorrhagic bowel syndrome and ileitis. It is speculated that each 20 to 24 hour out-of-feed event results in an increase in variation in growth within a population of pigs and results in a reduction in daily gain.*

**Introduction**

One of the most common responses to critics of modern production practices, especially confinement grow-finish facilities, is "we put pigs in these facilities to better provide for their daily needs." Yet, evidence is mounting that many producers are failing to meet this claim if the daily needs include unlimited access to feed.

A majority of finishing facilities have bulk bins and automated feed delivery systems. In theory, these bins and delivery systems assure an uninterrupted flow of feed to the feeder. In practice, growing-finishing pigs have varying disruptions in feed availability, some of which may have serious consequences.

**Causes**

The three major causes for out-of-feed events in grower-finisher facilities are:

1. human errors,
2. bridging of feed,
3. equipment malfunction.

*Human Errors.* Human errors generally are associated with empty bins, which occurs when feed is not ordered, prepared, and delivered in a timely manner. While preventable, this cause of out-of-feed events occurs more often than producers like to admit. It is most likely that this cause has increased as an increasing percentage of feed processing and delivery is provided by commercial mills, rather than on the farm. When feed is processed on the farm, an empty feeder or empty bin is relatively easy to resolve. The producer immediately processes enough feed to fill the bin and/or feeder.

However, with commercial mills, feed preparation and transport scheduling becomes an issue. Instead of a producer making an independent decision that feed processing is a high priority due to an empty (or near empty) bin or feeder, a central mill may require 24-hour or even 48-hour notice. Even if a mill accepts same-day orders, an order placed at 7 a.m. (when the empty bin is discovered) may not be delivered until

*(Continued on next page)*

mid-afternoon due to orders already received or previously scheduled. This means producers and production managers must estimate bin inventories and anticipate feed disappearance. Field experience suggests there is a wide variation in the ability of producers/managers to accomplish this vital task.

One method commonly used to reduce this source of out-of-feed events is the addition of a second bulk bin to the feed delivery line. In theory, one of the two bins is always full of feed. When one bin runs empty, the producer only has to close the delivery device on one bin and open up the other bin to restore feed access and place an order to refill the empty bin. However, production staff and/or supervisors will often by-pass this system by keeping both bins open since it is 'easy'. Now, the two bulk bins are in reality one bin, with no reserve supply.

There are several companies that offer bin monitoring equipment. There is an expense to this equipment, and until data is available to put a dollar value on the impact of out-of-feed events, producers (both owners and contract growers) have been reluctant to invest in this equipment.

*Feed Bridging.* A second cause of out-of-feed events is bridging of ground feed in bulk bins. In this case, feed is in the bin, but because of issues associated with flowability, it does not flow out of the bin into the feed delivery line. Producers often refer to this as "rat-holing" of feed in the bin.

Issues with bridging generally are limited to systems that use meal diets. Recent results from Kansas State University suggest that as particle size decreases, and the amount of fat added increases in corn-based diets, the angle of repose (an estimate of likelihood of bridging) increases. In the past 10 years, there has been a marked reduction in the average particle size for swine diets, driven by data which suggests a 1-1.5% improvement in feed conversion efficiency for each 100 micron reduction in particle size from 1000 to 500 microns. The current University of Nebraska and Purdue University recommendation is to process complete diets to an average particle size of 650 to 750 microns for all grains except wheat.

*Equipment Malfunction.* The final cause of out-of-feed events is equipment malfunction. Again, some producers have a larger incidence of this than others, generally related to the level of preventive repair and maintenance practiced. Intermixed with the above causes is the fact that out-of-feed events increase as facilities age, due to both equipment malfunctions and general producer apathy. To understand producer apathy, consider what happens in a new swine facility the first time an out-of-feed event occurs. In most cases, the producer panics since his assumption was the facility was built to provide for the pigs' every need, and an out-of-feed event will have production consequences. As facilities age and producers experience a variety of out-of-feed events, a general apathy often sets in. Producers with a fixed payment production contract ($x/pig space/year) often ask – what are/were the consequences to me as a grower from the out-of-feed event? Did the pigs become ill on the day they were out of feed? Did my payment change as a consequence of out-of-feed events? Did the pig owner notify me of a concern because of an out-of-feed event that they didn't even know about?

**Consequences**

Feed restriction in pigs is known to cause high levels of hunger-driven feeding motivation. In sows, which are commonly restricted-fed long-term, these high levels of feeding motivation are thought to contribute to the development of stereotypic behaviors. In grow-finish pigs exposed to feed restriction for short time periods the high levels of feeding motivation have been shown to manifest themselves in other ways. For example, feed restriction results in an increase in redirected behavior, such as pen-mate manipulation and an overall increase in activity. When food supply is reinstated, there is an increase in feeding rate (g/min), which in other species has been shown to be sustained even when feed supply subsequently remains constant. This suggests that repeated out-of-feed events lead to long term changes in the eating behavior of pigs.

There is considerable anecdotal evidence suggesting that when pigs are given access to feed following a period of deprivation, large amounts of fighting and aggressive behaviors occur. It is likely that this will adversely affect the welfare of all pigs within that pen. There is one report in the literature of increased competition and aggression for feeding spaces at feeding time when there was an unreliable or no signal of feed delivery. Difficulties in gaining access to feeders does appear to influence the number of feeding events and the length of these feeding events and it is possible that periods of feed unavailability will cause a disruption in the circadian pattern of many behaviors within the pen. Certainly, intermittent stressors are known to cause changes in circadian patterns of hormone secretion in pigs and of behavior in other species. There is also evidence that variation in weight gain increases when signals of feed availability are unreliable versus reliable.

Gastric ulceration is a common condition in modern pig production, with reports varying from 30 to 90% of all pigs in the

U.S. having some amount of stomach ulceration at slaughter. Short term feed deprivation (24 hours) was shown to create ulcers in growing pigs in studies at Purdue University. Periodic feed interruptions will likely create a similar effect in ad libitum fed pigs. While pigs being fed a 750 micron diet had most of these ulcers repaired by 28 days, those remaining on a finely ground diet (550 microns) or continuing to see weekly feed deprivations had increased stomach ulcerations.

Hemorrhagic bowel syndrome is a health concern because as much as 50% of all finishing deaths on some farms are attributed to this cause and sporadic outbreaks may result in upwards of 10 to 20% mortality in severe instances. It has been suggested by Michigan State University extension swine veterinarians that interruptions of feeding, such as occur with out-of-feed events, can be an inciting factor for hemorrhagic bowel syndrome. Veterinary pathologists also have speculated that inconsistent feed consumption leading to engorgement is a risk factor for hemorrhagic bowel syndrome.

If pigs miss one or more meals in a 24-hour period, they do not compensate for this missed feed intake by over consumption when feed does become available. This observation is based on on-farm recording of auger run times taken every 15 minutes using a commercially available monitoring system. If feed delivery fails sometime during the night and feed is rapidly made available first thing in the morning, there is little consequence. If feed delivery stops immediately after the previous morning's observations of pig health, etc., and feed isn't available until 4 p.m. on the following day, this is more than 24 hours of feed withdrawal (depending on the amount of feed in the feed hopper), a period of time likely to result in catabolism of body stores.

Pigs transported to slaughter plants and given water but no feed access during lairage have a relatively rapid loss of both live and carcass weight beginning approximately 18 hours after the last meal. The rate of liveweight loss was approximately 0.21%/hour and the loss in carcass weight was 0.13%/hour of fast in one study. The difference in rate of weight loss is presumably due to loss of intestinal fill, a loss that would be immediately restored with feed availability. USDA and University of Missouri researchers reported GI tract contents represented 50-60% of the total liveweight loss in pigs fasted 24 hours. Liver glycogen was almost completely depleted in pigs deprived of food for 12 and 18 hours in work done with slaughter pigs at packing plants.

It is quite possible that repeated out-of-feed events impact carcass composition. As early as 1970 there is a report that pigs fed ad libitum every other day with a one-day fasting period had a reduction in daily gain with minimal impact on feed conversion efficiency. However, carcass dressing percentage was reduced, in part because a higher percentage of weight at slaughter was visceral mass. In a later study, there was an increase in backfat depth for pigs fed every other day versus once or twice daily.

Using the equations of the 1998 National Research Council publication 'Nutrient Requirements of Swine', a 110 lb pig housed in thermo-neutral conditions requires 1990 kcal ME/day for maintenance or 83 kcal/hour. Assuming 20 hours for an out-of-feed event, this 110 lb pig uses body stores equivalent to just over 1 lb of a corn-soy diet (1500 kcal/lb). When feed does become available, the pig must consume 1 extra pound of feed to compensate for body stores lost in meeting the maintenance requirement, plus feed associated with the loss in growth. If the 110 lb pig was consuming 4.5-5.0 lb/day when feed was available, to compensate for the missed intake, feed consumption would have to increase to 5.5-6.0 lb just to compensate for maintenance and to restore growth to its previous rate, not including feed consumed to restore gut fill. In all likelihood, any tissue gain that is lost because of an out-of-feed event is not compensated for in subsequent meals based on on-farm feed delivery system monitoring. Thus, a 20-hour out-of-feed event can be thought of as the equivalent to 1 day longer to slaughter, a severe economic impact in production systems which have fixed time constraints on production flow.

**Conclusion**

Out-of-feed events are a growing concern in swine grow-finish facilities. Until production or research evidence is available, many care-takers of pigs remain complacent regarding the negative impacts of this management failure. Because pigs don't die, or appear to have clinical symptoms of disease within 24 hours of the out-of-feed event, there is no sense of urgency by many in the industry to eliminate, or at least significantly reduce the incidence of this failure. However, there are long term impacts, on pig welfare, health and performance that are only just beginning to be understood. As the industry achieves a greater understanding of these impacts it is logical to expect to see greater emphasis placed by all involved in grow-finish production to reduce the incidence of this management failure.

---

Mike Brumm, Extension Swine Specialist, University of Nebraska; Brian Richert, Extension Swine Specialist, Purdue University; Jeremy Marchant-Forde and Ruth Marchant-Forde, USDA-ARS Research Associates, Livestock Behavior Research Unit, Purdue University.

# Teeth Clipping — Have You Tried to Quit?

**Duane E. Reese**
**Barbara E. Straw**[1]

**Summary and Implications**

*Results from several experiments were reviewed to collect information on the value of piglet "needle-neeth" clipping. The incidence of facial and udder lesions generally is increased when teeth are left intact. However, there is no evidence that these lesions affect piglet mortality or weaning weight. Thus, based on the conditions of these experiments, there is no strong justification for teeth clipping. Many producers have abandoned teeth clipping. Besides saving labor, they report having fewer poor-doing piglets and joint infections that can result from teeth clipping. Some producers have tried to stop clipping, but because of greasy pig disease problems they have resumed. Producers who have not tried to stop clipping are advised to clip only half of the litters in a few farrowing groups and observe for possible problems.*

**Introduction**

Pork producers in the USA and other countries used to routinely clip piglets' "needle-teeth." However, due to a variety of factors, including, for example, regulatory action in Denmark, fewer piglets have their teeth clipped today. This paper will review the literature and report recent producer experience with teeth clipping to clarify the issue for producers who continue to teeth clip.

**Research Summary on Clipping**

Piglets are born with eight sharp, completed erupted "needle teeth" that they use to establish "ownership" over one or more teats. In the process of fighting for a position on the udder they may lacerate the face of littermates (Figure 1) and sow's udder.

*Facial lesions*

Several studies show that leaving teeth intact results in more piglet facial lesions. One group of British researchers using 550 piglets in 49 litters indicated the facial wounds they observed were relatively superficial and due to the lack of any ill effects on piglet health, weight gain or survival, questioned the importance of the wounds. Facial injury scores averaged 0.31 and 0.03 (0 = no wounds and 3 = several wounds) during the course of lactation for intact-teeth and clipped litters, respectively in that study. Using the same scoring system, another group of British researchers using 30 litters, reported facial injury scores averaged 0.37 and 0.10 for intact-teeth and clipped litters, respectively. There was a statistical difference between the injury score means in these studies; however, the low scores in the intact-teeth groups indicate the wounds were minor. Another study in Michigan that examined 318 litters found that during the first three days of life facial lesions were nearly twice as severe in litters with intact-teeth as in litters with clipped teeth, but lesions were only about 10% more severe in clipped litters at 13 days of age.

In contrast, facial lesions in the intact-teeth group monitored by Canadian researchers were severe enough to warrant removing nine out of 19 litters from their experiment.

*Udder damage*

The effect of intact teeth on udder laceration or damage rate is small according to two studies. In the UK, scientists reported mean udder injury scores (0 = no wounds and 3 = several wounds) for sows nursing intact-teeth litters averaged 0.05 over the course of a 21-day lactation period vs. 0.03 for those nursing clipped litters. Canadian researchers reported only one of 170 sows (0.6%) they used in the intact-teeth treatment group had lacerations on the udder. One hundred and twenty-five of the 170 sows (74%) nursed between nine and 14 piglets, an indication of the degree of competition at the udder in this study.

*Weight gain and mortality*

Despite the occurrence of facial and udder wounds, there

**Figure 1. Facial laceration caused by needle-teeth.**

**Figure 2. Infected mouth from teeth clipping.**

are no reports of decreased pre-weaning weight gain or increased mortality due to intact needle teeth. In the Michigan study, nursing growth rates were similar between pigs with clipped or intact-teeth, and pre-weaning mortality was actually lower among pigs with intact-teeth that were nursing first-litter sows or those of parity six or greater.

*Selective teeth clipping*

Canadian researchers concluded that piglets use their needle teeth to compete against littermates for milk and other resources. Therefore, selective teeth clipping may be an effective approach to improving the competitive ability of low-birth weight piglets. A total of 346 litters were assigned to either a control group where all piglets had their teeth clipped or an experimental group where one or more low-birth weight piglets had their teeth left intact.

Overall, the lower-birth weight piglets benefited from intact-teeth in terms of lower mortality and higher weight gain. However, that benefit was completely offset by a comparable disadvantage to the larger littermates whose teeth were clipped. Therefore, the treatments had no effect on overall piglet mortality or weight gain. It did reduce within-litter 21-day body weight variation by 15%, leading to more uniform weaning weights. However, selective clipping is not the only way to achieve more uniform weaning weights. Proper crossfostering within 24 hours of birth to even-up litter size and piglet bodyweight is effective. Also, identifying fall-outs quickly and providing them better nutrition will reduce weaning weight variation.

## Possible Teeth Clipping Problems

There are some problems associated with teeth clipping that would be eliminated if clipping was stopped. If teeth clipping is not done properly, it may result in damage to the gums or roots of the teeth. When teeth are clipped too close to the gum, the gums may be cut and left open to infection. Or if the tool used is dull or broken, instead of neatly cutting off the sharp points of the teeth, it may splinter or split the tooth down through the roots. Infection that gets into the roots is extremely painful and prevents the piglet from eating.

Often the first sign of a tooth infection is a poor-doing piglet. It usually will get up to nurse with its littermates, but suckles intermittently. Usually there is swelling of the snout that is noticeable from a normal view and when the mouth is opened the damage is obvious (Figure 2). The best way to prevent problems associated with broken teeth and mouth infections is to quit teeth clipping.

Joint infections in piglets sometimes are caused by the bacteria *Step suis*. The bacteria can enter the piglet's blood stream through damaged gums or broken teeth. If a piglet with a swollen joint also has infected teeth it is possible that damaged equipment or poor clipping technique is causing the problem.

## Reason to Clip

Facial lesions resulting from intact-teeth favor development of greasy pig disease in some herds. Greasy pig disease is often a problem in newly established gilt herds. It's caused by the bacteria, *Staphylococcus hyicus*, which lives on the skin surface. Cuts made in the skin from intact-teeth teeth allow the bacteria to enter the body. Some producers who quit teeth clipping have noticed more piglets with greasy pig disease and have resumed clipping.

## Conclusion

Many pork producers have learned that it is not necessary to clip teeth. In addition, to saving labor, they report having fewer poor-doing piglets and joint infections. These producers would not have known teeth clipping could be abandoned had they not tried to stop. Producers who have not tried to stop clipping are advised to clip only half of the litters in a few farrowing groups and observe for possible problems. Some producers have tried to stop clipping, but because of greasy pig disease problems they clip routinely.

---

[1]Duane E. Reese is an Extension Swine Specialist in the Department of Animal Sciences at the University of Nebraska. Barbara E. Straw is an Extension Veterinarian in the Department of Large Animal Clinical Sciences at Michigan State University. References are available at dreese1@unl.edu by request.

# Research Proposal Summary: Effects of Nutrition During Gilt Development on Sow Lifetime Productivity of Two Prolific Maternal Lines

**Rodger K. Johnson**
**Phillip S. Miller**[1]

**Summary and Implications**

*A four-parity study is proposed to examine the effects of nutritional manipulation during gilt development on subsequent sow performance. Gilts will be selected from two genetic lines that are highly prolific, but differ in rate and composition of growth. During the development period (45 to 250 lb), gilts will be provided either; i) ad libitum access to feed, or ii) ad libitum access to feed until 120 days of age (180 lb) and 75% of ad libitum feed intake thereafter (until first post-pubertal estrus). Sow and litter performance criteria will be examined. In addition, the economics of sow productivity and longevity will be evaluated using a return on equity model. Crossbred females of the Nebraska Index Line (NIL) with other maternal lines are being used in several herds within Nebraska and the United States. Not only has there been little research conducted investigating the effects of nutritional manipulation during gilt development on future sow productivity of the NIL crosses, but little information is available regarding how gilt development (as affected by nutritional manipulation) influences sow productivity of early-maturing, prolific sows. Results from this research project will help producers make decisions regarding the management of replacement gilts and define management scenarios that will optimize sow lifetime productivity. Project progress and research data updates will be provided annually in the University of Nebraska Swine Report until the completion of the study.*

**Introduction**

Ten to 20 years ago, annual sow death losses of 4 to 5% and annual sow replacement rates of 35 to 45% were typical in commercial swine herds. Today, much of the industry is experiencing average annual sow death losses of 10 to 12%, and death losses as high as 18% in some herds have been reported. As a result of increased sow death losses and other causes of involuntary culling, annual sow replacement rates of 45 to 55% are commonplace, and rates of 60% have occurred in some herds.

Causes of increased sow losses are not well documented, but sow housing systems and management practices have not changed greatly during this period. Gilts are developed to grow as rapidly as possible, mated at their second or third post-pubertal estrus, and mated again for the next litter within five to 10 days of weaning a litter (after a 15- to 21-day lactation period). It is commonly believed that the increased annual sow replacement rates are related to one or more of the following: genetic selection for prolificacy or selection for increased leanness and faster growth rate that has occurred in developing modern maternal lines.

In addition, it is generally accepted that gilts will be provided ad libitum access to feed until 230-250 lb; thereafter, gilts are limit fed until flushing/breeding at approximately 300 lb. This system of gilt management may not be appropriate for all maternal lines. Specifically, gilts of prolific, early-maturing lines may be able to enter the sow herd at body weights < 300 lb without compromising lifetime productivity and(or) health status. Therefore, protocols should consider controlling (limiting) feed intake prior to 230-250 lb.

In this project, we propose to determine whether alternative gilt nutritional development strategies affect longevity and lifetime productivity of prolific lines of pigs. Gilts of two lines will be fed two different dietary regimens during the gilt development period in a $2 \times 2$ factorial arrangement of treatments and evaluated for reproduction traits through four parities. Two highly prolific genetic lines that differ in rate and composition of growth will be used. The two genetic groups will be produced by mating commercial Large White-Landrace cross females, used regularly in the University of Nebraska (UNL) nutrition research program, with semen of boars of another commercial maternal line or with Nebraska Index Line (NIL) boars.

*Development of the Nebraska*

**Table 1. Average expected performance for P1 and P2 gilts based on NPPC Maternal Line Evaluation Project[a].**

| Trait | P1 | P2 |
|---|---|---|
| ADG, 10 lb to 150 d of age, lb/d | 1.35 | 1.20 |
| $10^{th}$ rib BF at 212 lb, in | 0.63 | 0.71 |
| Loin depth at 212 lb, in | 2.42 | 2.25 |
| Age at first estrus, d | 222 | 209 |
| Gilt farrowing rate, % | 76 | 92 |
| Total born/litter, avg of 4 parities | 11.3 | 12.0 |
| Wean to service interval, d | 11.0 | 9.6 |
| Percentage of gilts with 4 litters | 49.0 | 69.9 |

[a]P1: A cross of boars of commercial line ($L_M$) with UNL Large White-Landrace gilts. **P2**: A cross of $L_M$ with Nebraska Index Line gilts.

*Index Line.* The University of Nebraska has a long history of research in genetics and physiology of reproduction. Early work determined that ovulation rate is 35-40% heritable and responds to selection, but because of limitations in embryonic survival and uterine capacity, only about 25% of the increase in ovulation rate is realized in increased litter size. The limitation was overcome by selecting for an index of ovulation rate, embryonic survival, uterine capacity and litter size. During 21 generations of selection, the NIL that averages 13.5 to 14 pigs per litter, 45% greater than the control, was developed. Crossbred gilts of NIL with Monsanto Choice Genetics Line 34 (GPK34) were entered into the NPPC Maternal Line Evaluation Project (MLE) along with gilts of five other commercial organizations. The NIL × GPK34 (a gilt expected to be similar to the one to be developed for this study) had 30 to 50% greater production through four parities than the other females. As a result, the NIL was released to the industry and is being used in several breeding programs. It currently is recognized as one of the most prolific females available to swine breeders. Therefore, the objective of this proposal is to determine whether alternative gilt development strategies affect longevity and lifetime production of two prolific maternal lines.

## Procedures

*Description of gilts to be evaluated:*

Gilt Population I **(P1)**: A cross of boars of commercial maternal line ($L_M$) with UNL Large White-Landrace gilts

Gilt Population II **(P2)**: A cross of $L_M$ with NIL gilts

The UNL Large White and Landrace lines and the commercial line $L_M$ are industry lines selected for increased prolificacy, growth rate, and leanness. The NIL is a line produced within the UNL genetics research program that has been selected 21 generations for increased prolificacy with very little selection for increased growth and improved leanness. P1 and P2 gilts are expected to have reproductive, growth, and lean similar to that of certain crosses that were evaluated in the NPPC MLE (Table 1).

Pigs will be housed and procedures will be conducted, at the UNL Swine Unit, Ithaca, Neb. All procedures and treatments will be in accordance with UNL Institutional Animal Care and Use Committee guidelines. Breedings to produce the aforementioned lines will initiate in early September, 2004. Accordingly, females (50 litters available per treatment; 25 litters/line) will be born in January, 2005 (Replicate 1). The breeding regimen used to develop Replicate 1 will be repeated beginning January, 2005 to create Replicate 2. Therefore, 200 gilts (50 gilts per population × dietary treatment) will be used. Females will be selected for the experiment at or prior to weaning (17 to 21 days postfarrowing). Two females per litter will be identified and randomly selected for future allotment to one of the dietary regimens (see below). After weaning, all gilts will be group-housed in a modified-open-front building (approx. 8 to 10 pigs/pen). Gilts will have ad libitum access to a standard three-phase grower diet system (Phase 1, 1.15% lysine; Phase 2, 1.00% lysine; Phase 3, 0.90% lysine; 45 to 80 lb, 80 to 130 lb, and 130 to 180 lb, respectively). Diets will be corn-soybean meal-based with .15% crystalline lysine included.

At approximately 120 days (180 lb), half (n = 25/line) of the gilts will continue to be given ad libitum access of a 0.70 % lysine diet (0.70% Ca, 0.60% P; **TRT 1**) until breeding. The remaining 25 gilts/line will be limit fed (75% of ad libitum intake) a diet containing 0.93% lysine (1.0% Ca, .80% P; **TRT 2**) until breeding. At 140 days of age, gilts will be heat checked twice daily using an intact boar. Pubertal estrus will be recorded and matings will begin at the first post-pubertal estrus. From day 0 to breeding, growth performance criteria and real-time ultrasound measurements (back fat (BF) thickness and longissimus muscle area (LMA)) will be recorded every two weeks. Gestation and lactation management will be identical for all sows. Sows will receive approximately 4 lb of a 0.55% lysine diet during gestation and have ad libitum access to lactation diets (1.0% lysine). Body weight, BF and LMA will be recorded at each farrowing and weaning. Any cross fostering to equalize litter size will be conducted within three days

*(Continued on next page)*

postfarrowing. The following sow performance criteria will be collected: litter size (total and live), number and weight of pigs at weaning, and return to estrus (relative to weaning date). Pigs will be weaned at 17 to 21 days post weaning. Daily heat checking will be initiated three days postweaning until expression of estrus. Sows will be bred at the first or second estrus postweaning. Sows that are not bred by day 21 postweaning will be culled. Sows will remain on treatment for a maximum of four consecutive parities. Criteria for gilts to be allocated to treatment and sow culling procedures to be used are described in the Maternal Line National Genetic Evaluation Program Results (NPPC; April, 2000). The economics of sow productivity and longevity will be evaluated using the NPPC Return on Equity (ROE) Model.

**Anticipated Results**

Based on the MLE, when gilts were developed with the common industry practices, expected differences between P1 and P2 gilts are described in Table 1. We hypothesize that feed restriction (prior to 250 lb) will not adversely affect productivity or health status of the P2 gilt line; however, reduced energy intake during late development will reduce lifetime productivity of the P1 line.

[1]Rodger K. Johnson and Phillip S. Miller are professors in the Department of Animal Science.

# Effect of Increasing Dietary Crude Protein Concentration on Growth Performance and Serum Insulin-Like Growth Factor-I Concentration in Barrows and Gilts

**Robert L. Fischer**
**Phillip S. Miller[1]**

**Summary and Implications**

*A study was conducted to investigate the effects of increasing dietary protein intake on growth performance, carcass composition and serum insulin-like growth factor-I (IGF-I) concentration in growing-finishing barrows and gilts. Seventy crossbred pigs (35 barrows and 35 gilts) with an initial body weight of 75.1 lb were used in a 26-day growth study. The pigs were allocated randomly to one of four dietary treatments. The diets were standard corn soybean meal diets, which were formulated to contain 10, 14, 18, or 22% crude protein by changing the ratio of corn to soybean meal in the diet. At the termination of the experiment, pigs were slaughtered to determine carcass accretion rates of protein, water, fat and ash. Pig and feeder weights were recorded weekly for the determination of average daily gain (ADG), average daily feed intake (ADFI), and calculation of feed efficiency (ADG/ADFI). Weekly blood samples were collected to evaluate dietary effects on plasma urea and IGF-I concentrations. There was no difference (P > 0.10) in ADFI among treatments; however barrows consumed more feed than gilts (3.94 versus 3.70 lb/d; P = 0.01) throughout the 26-day period. Dietary protein concentration had linear and quadratic effects on ADG and ADG/ADFI (P < 0.01). Also, barrows gained weight faster (ADG: 1.57 versus 1.41 lb; P < 0.01) and were more efficient (ADG/ADFI: 0.40 versus 0.38 lb/lb; P = 0.02) than gilts throughout the experiment. Increased dietary protein concentration resulted in increased fat-free lean gain, cold carcass weight (linear, P < 0.01; quadratic, P < 0.01) and dressing percentage (quadratic effect, P < 0.01). Protein concentration had a linear effect (P < 0.01) on plasma urea during weeks 1 through 4 and had a quadratic effect (P < 0.01) during weeks 1 and 4 of the experiment. Also, dietary crude protein concentration had linear and quadratic effects (P < 0.01) on serum IGF-I concentrations during weeks 2 and 4 of the experiment. In summary, dietary protein concentration had linear and quadratic effects on final body weight, ADG, feed efficiency, fat-free lean gain, cold carcass weight, plasma urea and serum IGF-I concentration. Thus, the interesting finding in this experiment was that the decrease in fat-free lean gain and protein accretion rate in pigs fed the 18% CP diet were not associated with a decrease in serum IGF-I concentration. This finding suggests that nutritional and (or) physiological factors are inhibiting the actions of IGF-I by causing a decrease in protein accre-*

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

| Item | Dietary protein concentration, % | | | |
|---|---|---|---|---|
| | 10 | 14 | 18 | 22 |
| **Ingredient, %** | | | | |
| Corn | 89.10 | 79.00 | 69.10 | 59.00 |
| Soybean meal, 46.5% CP | 5.50 | 15.75 | 25.75 | 36.00 |
| Tallow | 3.00 | 3.00 | 3.00 | 3.00 |
| Dicalcium phosphate | 1.05 | 1.00 | 0.95 | 0.85 |
| Limestone | 0.70 | 0.65 | 0.58 | 0.55 |
| Salt | 0.30 | 0.30 | 0.30 | 0.30 |
| Vitamin premix[a] | 0.20 | 0.20 | 0.20 | 0.20 |
| Mineral premix[b] | 0.15 | 0.15 | 0.15 | 0.15 |
| **Analyzed nutrient composition** | | | | |
| Crude protein, % | 10.72 | 13.79 | 17.39 | 21.93 |
| Dry matter, % | 89.71 | 89.41 | 89.84 | 89.77 |
| Calcium, % | 0.60 | 0.71 | 0.60 | 0.68 |
| Total phosphorus, % | 0.48 | 0.59 | 0.53 | 0.66 |
| Crude fat, % | 5.24 | 5.29 | 5.21 | 5.16 |
| **Calculated nutrient composition** | | | | |
| Lysine, % | 0.39 | 0.65 | 0.90 | 1.16 |
| ME, Mcal/lb[c] | 1.57 | 1.57 | 1.57 | 1.57 |

[a]Supplied per kilogram of diet: retinyl acetate, 4,400 IU; cholecalciferol, 440 IU; α-tocopherol acetate, 24 IU; menadione sodium bisulfite, 3.5 mg; riboflavin, 8.8 mg; d-pantothenic acid, 17.6 mg; niacin, 26.4 mg; vitamin $B_{12}$, 26.4 µg.
[b]Supplied per kilogram of diet: Zn (as ZnO), 128 mg; Fe (as $FeSO_4 \cdot H_2O$),128 mg; Mn (as MnO), 30 mg; Cu (as $CuSO_4 \cdot 5\ H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$), 0.26 mg; Se (as $Na_2SeO_3$), 0.3 mg.
[c]Metabolizable energy.

*tion rate. Thus, the future focus of this research is to determine the effects of dietary crude protein and crystalline amino acids on serum IGF-I concentration and metabolic actions.*

## Introduction

Excessive excretion of nitrogen by livestock operations is a major environmental concern. A consequence of excess nitrogen excretion is the potential for leaching of nitrates into groundwater and from runoff of nitrates into surface water. Thus, a major factor that has stimulated interest in the use of low-protein amino-acid supplemented diets is the potential positive impact on the environment. It is estimated that when growing-finishing pigs are fed low-protein amino acid-supplemented diets there is a 30% reduction in nitrogen excretion. Nutritional and hormonal factors are major determinants of animal growth, but the mechanisms of how protein (amino acids) influence the hormonal control of protein accretion in growing animals remains relatively undefined. Protein accretion in growing animals is mediated indirectly by pituitary growth hormone. When growth hormone is bound to specific receptors, it stimulates the production of insulin-like growth factor-I (IGF-I). Although growth hormone is the primary stimulus for IGF-I synthesis, many nutritional factors (i.e., protein intake, energy intake and essential amino acid intake) affect the production and action of IGF-I in the growing animal. Therefore, the current research seeks to augment the current knowledge of how the use of crystalline amino acids affects protein accretion by gaining a greater understanding of how IGF-I is affected by dietary concentrations of crude protein (amino acids) in swine growing-finishing diets.

The long-range goal of this research is to determine the concentrations of essential amino acids and the dietary protein ingredient (protein-bound versus crystalline amino acids) that will optimize IGF-I expression in growing-finishing pigs to maximize protein accretion. The objective of this experiment was to demonstrate *in vivo* the effect of increasing dietary protein intake on serum IGF-I concentration in barrows and gilts.

## Procedures

*Animals and treatments*

Seventy crossbred [Danbred × (Danbred × NE White Line)] barrows and gilts were used in a 26-day growth study. Pigs averaged 75.1 and 114.0 lb at the initiation and termination of the experiment, respectively. Three barrows and three gilts were selected randomly for an initial slaughter group in order to collect tissue samples and determination of carcass composition. The remaining 64 pigs (32 barrows and 32 gilts) were assigned randomly to one of four dietary treatments. Diets (Table 1) were standard corn soybean meal diets and formulated to contain 10, 14, 18, or 22% crude protein (CP) by changing the ratio of corn to soybean meal in the diet. Diets were fortified with vitamins and minerals to meet or exceed NRC (1998) requirements for 45-lb pigs. Pigs were housed in an environmentally controlled building and allowed ad libitum access to feed and water throughout the experiment.

*Data and sample collections*

Pig and feeder weights were recorded weekly for the determination of average daily gain (ADG), average daily feed intake (ADFI), and calculation of feed efficiency (ADG/ADFI). Fat-free lean gain (FFLG) was calculated using the National Pork Producers Council (2000) equations. Initial fat-free lean was estimated using initial body weight and final fat-free lean was calculated

*(Continued on next page)*

**Table 2. Effect of protein concentration on growth performance of growing barrows and gilts.**

| | | Dietary protein concentration, % | | | | | P-Value | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | | 10 | 14 | 18 | 22 | SEM | Trt | Sex | Trt x Sex | Linear | Quadratic |
| Total number of pigs | | 16 | 16 | 16 | 16 | | | | | | |
| | Barrows | 8 | 8 | 8 | 8 | | | | | | |
| | Gilts | | 8 | 8 | 8 | 8 | | | | | |
| Growth performance | | | | | | | | | | | |
| | Initial wt., lb | 75.17 | 75.61 | 74.93 | 74.71 | 0.510 | NS | NS | NS | NS | NS |
| | Barrows | 76.18 | 74.93 | 74.71 | 74.51 | 0.721 | | | | | |
| | Gilts | 74.18 | 76.29 | 75.15 | 74.88 | 0.721 | | | | | |
| | Final wt., lb | 99.31 | 113.07 | 119.69 | 123.92 | 1.296 | < 0.01 | < 0.01 | NS | < 0.01 | < 0.01 |
| | Barrows | 101.50 | 114.75 | 120.83 | 126.92 | 1.819 | | | | | |
| | Gilts | 97.15 | 111.37 | 118.54 | 120.90 | 1.819 | | | | | |
| d 0 to 26 | ADG, lb [a] | 0.93 | 1.43 | 1.72 | 1.89 | 0.044 | < 0.01 | < 0.01 | NS | < 0.01 | < 0.01 |
| | Barrows | 0.97 | 1.52 | 1.76 | 2.01 | 0.064 | | | | | |
| | Gilts | 0.88 | 1.35 | 1.68 | 1.76 | 0.064 | | | | | |
| | ADFI , lb [b] | 3.64 | 3.92 | 3.81 | 3.92 | 0.097 | NS | 0.01 | NS | NS | NS |
| | Barrows | 3.84 | 4.12 | 3.90 | 3.97 | 0.137 | | | | | |
| | Gilts | 3.44 | 3.75 | 3.73 | 3.88 | 0.137 | | | | | |
| | ADG/ADFI | 0.25 | 0.37 | 0.45 | 0.48 | 0.007 | < 0.01 | 0.02 | 0.05 | < 0.01 | < 0.01 |
| | Barrows | 0.25 | 0.37 | 0.45 | 0.51 | 0.010 | | | | | |
| | Gilts | 0.26 | 0.36 | 0.45 | 0.46 | 0.010 | | | | | |

[a]ADG = average daily gain.
[b]ADFI = average daily feed intake.

**Table 3. Effect of protein concentration on ultrasound and carcass measurements of growing barrows and gilts.**

| | | Dietary protein concentration, % | | | | | P-Value | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | | 10 | 14 | 18 | 22 | SEM | Trt | Sex | Trt x Sex | Linear | Quadratic |
| Total number of pigs | | 16 | 16 | 16 | 16 | | | | | | |
| | Barrows | 8 | 8 | 8 | 8 | | | | | | |
| | Gilts | 8 | 8 | 8 | 8 | | | | | | |
| Ultrasound measurements (day 26) | | | | | | | | | | | |
| | Backfat, in | 0.49 | 0.48 | 0.48 | 0.44 | 0.018 | NS | NS | NS | NS | NS |
| | Barrows | 0.51 | 0.49 | 0.50 | 0.44 | 0.027 | | | | | |
| | Gilts | 0.48 | 0.46 | 0.45 | 0.45 | 0.027 | | | | | |
| | LMA, $in^2$ [a] | 2.64 | 3.21 | 3.51 | 3.59 | 0.082 | < 0.01 | NS | NS | < 0.01 | < 0.01 |
| | Barrows | 2.58 | 3.19 | 3.40 | 3.50 | 0.116 | | | | | |
| | Gilts | 2.69 | 3.24 | 3.62 | 3.68 | 0.116 | | | | | |
| | FFLG, lb/d [b c] | 0.33 | 0.60 | 0.75 | 0.84 | 0.020 | < 0.01 | NS | NS | < 0.01 | < 0.01 |
| | Barrows | 0.31 | 0.62 | 0.73 | 0.87 | 0.028 | | | | | |
| | Gilts | 0.34 | 0.59 | 0.77 | 0.82 | 0.028 | | | | | |
| Carcass measurements | | | | | | | | | | | |
| | Hot carcass wt., lb | 69.57 | 80.28 | 86.79 | 88.00 | .858 | < 0.01 | 0.01 | NS | < 0.01 | < 0.01 |
| | Barrows | 71.02 | 81.14 | 87.16 | 89.72 | 1.211 | | | | | |
| | Gilts | 68.11 | 79.40 | 86.41 | 86.28 | 1.211 | | | | | |
| | Cold carcass wt., lb | 67.52 | 77.26 | 83.48 | 84.65 | 0.964 | < 0.01 | < 0.01 | NS | < 0.01 | < 0.01 |
| | Barrows | 68.93 | 78.43 | 84.36 | 86.74 | 1.360 | | | | | |
| | Gilts | 66.11 | 76.12 | 82.62 | 82.56 | 1.360 | | | | | |
| | Dressing, % | 69.71 | 69.88 | 70.99 | 69.24 | 0.325 | < 0.01 | < 0.05 | NS | NS | < 0.01 |
| | Barrows | 69.55 | 69.37 | 70.59 | 68.96 | 0.458 | | | | | |
| | Gilts | 69.87 | 70.38 | 71.39 | 69.53 | 0.458 | | | | | |
| | Liver, lb | 1.70 | 1.89 | 2.12 | 2.40 | 0.050 | < 0.01 | 0.01 | NS | < 0.01 | NS |
| | Barrows | 1.77 | 1.94 | 2.16 | 2.49 | 0.071 | | | | | |
| | Gilts | 1.63 | 1.84 | 2.07 | 2.31 | 0.071 | | | | | |

[a]LMA = longissimus muscle area.
[b]FFLG = fat-free lean gain.
[c]Calculated using equations derived from NPPC, 2000.

**Table 4. Effect of protein concentration on carcass accretion rates of growing barrows and gilts.**

| | Dietary protein concentration, % | | | | | P-Value | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Item | 10 | 14 | 18 | 22 | SEM | Trt | Sex | Trt x Sex | Linear | Quadratic |
| Total number of pigs | 16 | 16 | 16 | 16 | | | | | | |
| Barrows | 8 | 8 | 8 | 8 | | | | | | |
| Gilts | 8 | 8 | 8 | 8 | | | | | | |
| Empty body weight, lb | 95.34 | 110.07 | 117.64 | 121.63 | 1.213 | < 0.01 | < 0.01 | NS | < 0.01 | < 0.01 |
| Barrows | 97.51 | 111.75 | 118.89 | 124.08 | 1.711 | | | | | |
| Gilts | 93.21 | 108.38 | 116.38 | 119.20 | 1.711 | | | | | |
| Protein, g/d | 41.80 | 82.70 | 104.96 | 119.95 | 2.671 | < 0.01 | NS | < 0.05 | < 0.01 | < 0.01 |
| Barrows | 42.02 | 85.92 | 101.98 | 128.24 | 3.778 | | | | | |
| Gilts | 41.57 | 79.47 | 107.93 | 111.67 | 3.778 | | | | | |
| Fat, g/d | 163.32 | 160.46 | 168.88 | 141.73 | 10.725 | NS | NS | NS | NS | NS |
| Barrows | 179.20 | 155.89 | 185.30 | 137.45 | 15.167 | | | | | |
| Gilts | 147.45 | 165.02 | 152.46 | 146.02 | 15.167 | | | | | |
| Water, g/d | 130.25 | 243.26 | 322.47 | 351.05 | 8.745 | < 0.01 | 0.02 | NS | < 0.01 | < 0.01 |
| Barrows | 135.36 | 258.23 | 320.25 | 377.07 | 12.368 | | | | | |
| Gilts | 125.14 | 228.29 | 324.69 | 325.03 | 12.368 | | | | | |
| Ash, g/d | 8.27 | 11.24 | 10.81 | 12.50 | 0.891 | 0.01 | NS | 0.05 | < 0.01 | NS |
| Barrows | 7.91 | 12.38 | 10.58 | 15.31 | 0.891 | | | | | |
| Gilts | 8.65 | 10.10 | 11.03 | 9.69 | 1.259 | | | | | |

using real-time ultrasound backfat and longissimus muscle area collected on day 26 of the experiment. Plasma urea and serum insulin-like growth factor-I (IGF-I) concentrations were determined in blood collected weekly throughout the experiment.

*Statistical analysis*

Data were analyzed as a completely randomized design using PROC MIXED of SAS (1999). The main effects in the statistical model were dietary protein concentration (10, 14, 18, and 22% CP) and sex. In all analyses, pig was the experimental unit. Only linear and quadratic effects are presented for variables in which the main effect of CP was significant ($P < 0.05$).

## Results and Discussion

*Growth performance*

The response of ADG, ADFI, and ADG/ADFI to dietary treatments is shown in Table 2. There was no difference ($P > 0.10$) in ADFI among treatments; however, barrows consumed more feed than gilts (3.94 versus 3.70 lb/d; $P = 0.01$) throughout the 26-day experimental period. Protein concentration had linear and quadratic effects on ADG and feed efficiency ($P < 0.01$). Average daily gain increased as the dietary crude protein concentration increased from 10% (0.93 lb/d) to 22% (1.89 lb/d; a 49% improvement in gain). Feed efficiency responded similarly as ADG. Pigs fed the 10% dietary CP had the lowest ADG/ADFI (0.25) and pigs fed the diet containing 22% CP had the greatest ADG/ADFI (0.48; a 52% improvement in feed efficiency). Barrows gained weight faster (1.57 versus 1.41 lb/d; $P < 0.01$) and were more efficient (0.40 versus 0.38 lb/lb; $P = 0.02$) than gilts throughout the experiment.

*Carcass characteristics*

Real-time ultrasound measurements recorded on day 26 are summarized in Table 3. At the end of the experiment, there were no crude protein (dietary treatments) or sex effects on backfat (BF) depth; however, crude protein concentration resulted in linear and quadratic effects ($P < 0.01$) on ultrasound longissimus muscle area (LMA). Longissimus muscle area was similar among pigs fed diets containing 18 and 22% CP (3.51, 3.59 $in^2$, respectively); however, pigs fed the 10 and 14% dietary CP had a reduction in LMA (3.21 and 2.64 $in^2$, respectively). Protein concentration had linear and quadratic effects on fat-free lean gain ($P < 0.01$). Pigs fed the 22% CP diet had the greatest fat-free lean accretion rate (0.84 lb/d). Increased dietary protein concentration resulted in increased hot and cold carcass weights (linear and quadratic, $P < 0.01$) and a quadratic effect ($P < 0.01$) in carcass dressing percentage. Barrows had greater hot (82.3 versus 80.0 lb) and cold (79.6 versus 77.0 lb) carcass weights than gilts. Gilts had a greater ($P < 0.05$) carcass dressing percentage than barrows (70.3 versus 69.6%). Increased crude protein concentration linearly affected ($P < 0.01$) liver weight. Barrows had heavier liver weights (2.09 lb) than gilts (1.96 lb), which was apparently a result of greater ADFI of barrows. There were no differences ($P > 0.10$) in the other internal organ weights (i.e. heart, lungs, spleen, stom-

*(Continued on next page)*

ach, small intestine, large intestine, and mesentery) among dietary treatments and between barrows and gilts (data not shown).

*Carcass accretion rate*

The effect of dietary protein concentration on carcass accretion rates in growing barrows and gilts are shown in Table 4. Dietary protein concentration had linear and quadratic effects on empty body weight and protein and water accretion rates ($P < 0.01$). Empty body weight increased as the dietary concentration of crude protein increased from 10% (95.3 lb) to 22% dietary CP (121.6 lb). Barrows had greater ($P < 0.01$) empty body weights than gilts (113.1 versus 109.4 lb). Protein accretion rates increased from 41.8 g/d in pigs fed the 10% CP diet to 120 g/d in pigs fed the 22% CP diet. This increase in protein accretion rate is supported by the increase in water accretion rates as dietary protein concentration increased. The greater protein and water accretion rates in pigs fed the diets with a greater concentration of crude protein follow the same pattern shown for fat-free lean gain data.

*Blood metabolites*

The effects of dietary crude protein on plasma urea concentration are presented in Figure 1. The sex effect observed on day 0 indicates that at a body weight of 75 lb gilts selected for this experiment were more efficient in utilizing dietary protein than barrows fed the same diet. Protein concentration had linear and quadratic effects ($P < 0.01$) on plasma urea concentration during weeks 1 and 4 of the experiment and a linear effect during weeks 2 and 3. Barrows and gilts fed the 10 and 14% CP diets had similar plasma urea concentrations throughout the experiment. Although barrows fed the 18% CP diet had an intermediate concentration of plasma urea and a concentration that remained similar throughout the experiment, gilts fed the 18% CP diet had a low plasma urea concentration of d 0 and 7 which increased on day 14 and 21 and then decreased on day 26. This fluctuation in plasma urea concentration in gilts fed the 18% CP diet is similar to the change in ADFI of these gilts which was 3.57, 3.88, 3.90, and 3.55 lb/d for weeks 1 through 4, respectively. Pigs fed the 22% CP diet had the greatest plasma urea concentration throughout the experiment. The plasma urea data indicate that the CP requirement for gilts during the 4-week experimental period was > 18% CP which was

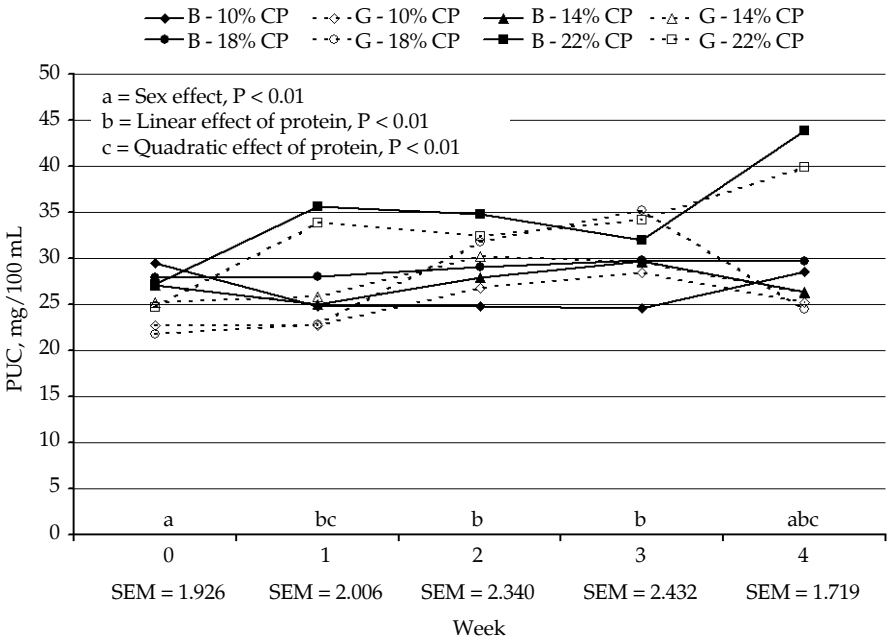



**Figure 1. Response of plasma urea concentration (PUC) to experimental diets by week.**

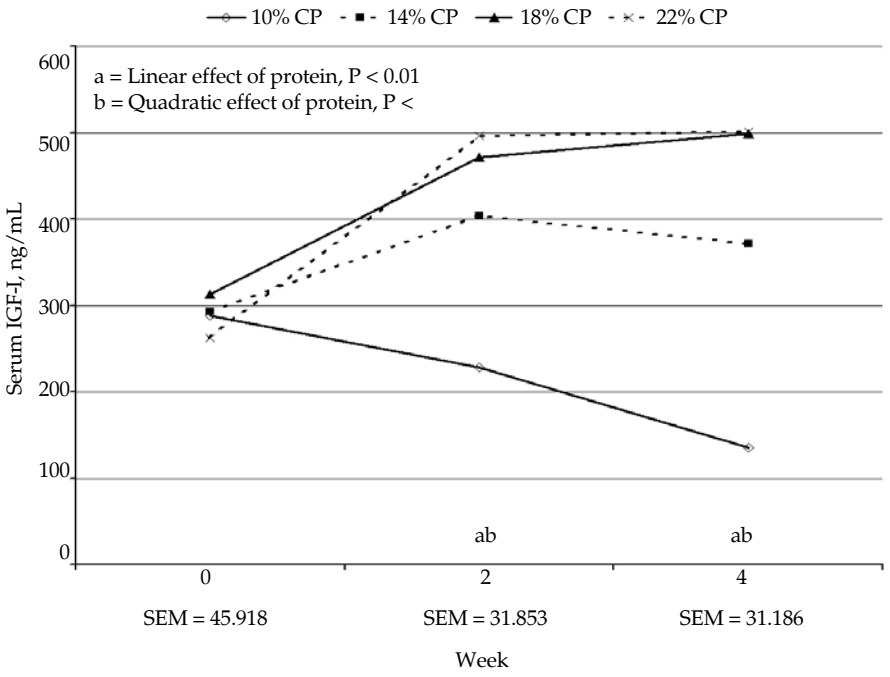



**Figure 2. Response of serum insulin-like growth factor-I (IGF-I) to experimental diets by week.**

also supported by the FFLG data.

Serum IGF-I concentrations are presented in Figure 2. Protein concentration had linear and quadratic effects ($P < 0.01$) on serum IGF-I concentration during weeks 2 and 4 of the experiment. There were no sex effects detected for serum IGF-I concentration, thus the data for barrows and gilts within dietary crude protein concentration were pooled and presented in Figure 2. Pigs fed the diet containing 10% CP had the lowest IGF-I concentration throughout the experiment and pigs fed the 18 and 22% CP had similar IGF-I concentration during weeks 2 and 4 of the experiment. These serum IGF-I concentrations indicate that the production and release of IGF-I into the blood is inhibited by the consumption of a 10 or 14% CP diet. This reduction in serum IGF-I is supported by the reduced fat-free lean accretion rates calculated for the pigs consuming the 10 and 14% crude protein diet. However, pigs fed the 18 and 22% CP diets had numerically similar serum IGF-I concentrations, and pigs fed the 18% CP diet had a significant decrease in FFLG as compared to pigs fed the 22% CP diets. These results suggest that the consumption of a diet marginally deficient in CP (18%) does not inhibit the production of IGF-I. However, the actions of IGF-I (i.e., muscle protein accretion) are partially inhibited. This diminished action of IGF-I is supported by the reduction in FFLG observed for pigs fed the 18% CP diet.

### Conclusions

Results from this experiment demonstrate that growing pigs respond to increased dietary crude protein concentration, which is supported by the improvement in ADG, feed efficiency and fat-free lean gain in pigs fed up to 22% crude protein. A similar effect was detected in plasma urea concentration. Pigs fed the 22% CP diet had an increase concentration of plasma urea compared to the pigs fed the 10, 14, and 18% CP diet, indicating that the CP requirement of gilts in this experiment was > 18% CP. However, serum IGF-I concentrations were decreased in pigs fed the 10 and 14% CP diets, indicating that the consumption of a diet below the pigs dietary crude protein requirement (18%) was not always associated with a reduction in IGF-I serum concentration. Therefore, future research in this area will focus on the relationship between carcass protein accretion and serum IGF-I concentration. Also, the effect of crystalline amino acids will be investigated to determine their effects on serum IGF-I concentration and how the pattern of dietary crystalline amino acid supplementation can be manipulated in diets for growing-finishing pigs without creating negative effects on carcass protein accretion rates.

[1]Robert L. Fischer is a research technologist and graduate student and Phillip S. Miller is a professor in the Department of Animal Science.

# Development of a NCR-42 Vitamin-Trace Mineral Mix

**Laura R. Albrecht**
**Robert L. Fischer**
**Phillip S. Miller[1]**

### Summary and Implications

*A vitamin-trace mineral mix (NCR-42 VTMM) and a vitamin B-safety pak (biotin, choline, folacin, thiamin and vitamin $B_6$) were formulated as possible common sources of nutrients for cooperative projects for the NCR-42 (North Central Regional) committee on swine nutrition. The adequacy of the NCR-42 VTMM and the vitamin B-safety pak were evaluated in a four-week growth trial with weanling pigs. The pigs (weaned 18-23d) were fed one of six diets: 1) NC, negative control, a common nursery diet with vitamins at minimum levels (VTMM OX); 2) treatment 1, a common nursery diet with VTMM vitamins at 100% of NRC 1998 requirements for 5 to 45 lb pigs; 3) treatment 2, a common nursery diet with VTMM vitamins at 300% of NRC 1998 requirements for 5 to 45 lb pigs; 4) treatment 3, a common nursery diet with VTMM vitamins at 100% of NRC 1998 requirements for 5 to 45 lb pigs and B-safety pak at 100% of NRC 1998 requirements for 5 to 45 lb pigs; 5) treatment 4, a common nursery diet with VTMM vitamins at 300% and B-safety pak at 300% of NRC 1998 requirements for 5 to 45 lb pigs; 6) UNL, a common nursery diet with the concentration of vitamins/minerals regularly fed in University of Nebraska (UNL) diets. Overall, there were no differences ($P > 0.10$) in average daily gain (ADG), average daily feed intake (ADFI), or feed efficiency (ADG/ADFI). However, numerically, there were increases in ADG and ADFI as the concentrations of minerals and vitamins increased. Pigs receiving the diet conforming to the typical University of Nebraska supplement had increased ADG, ADFI and feed efficiency compared to the negative control. Results from this study will be collectively examined with identical studies conducted at other research stations.*

*(Continued on next page)*

**Table 1. Composition of phase I and phase II diets.**

| | Phase[ab] | | | | | | Phase II[ac] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ingredients, % | NC | Trt 1 | Trt 2 | Trt 3 | Trt 4 | UNL | NC | Trt 1 | Trt 2 | Trt 3 | Trt 4 | UNL |
| Corn | 38.14 | 37.99 | 37.69 | 37.09 | 37.39 | 38.04 | 49.06 | 48.91 | 48.61 | 48.81 | 48.31 | 48.96 |
| Soybean meal, 46.5% CP | 22.77 | 22.77 | 22.77 | 22.77 | 22.77 | 22.77 | 24.82 | 24.82 | 24.82 | 24.82 | 24.82 | 24.82 |
| Whey | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| Blood plasma | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Blood cells | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Lactose | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dicalcium phosphate | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 | 1.61 |
| Limestone | 0.83 | 0.83 | 0.83 | 0..83 | 0.83 | 0.83 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| Sodium Chloride | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| Fat | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Mecadox® | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| NCR-42 VTMM_03[d] | 0.30 | 0.45 | 0.75 | 0.45 | 0.75 | 0.00 | 0.30 | 0.45 | 0.75 | 0.45 | 0.75 | 0.00 |
| B-safety pak[d] | 0.00 | 0.00 | 0.00 | 0.10 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.30 | 0.00 |
| UNL vitamin mix[c] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |
| UNL mineral mix[f] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |

[a]NC = negative control, Trt 1 = VTMM 100%, Trt 2 = VTMM 300%, Trt 3 = VTMM 100%/B-safety pak 100%, Trt 4 = VTMM 300%/B-safety pak 300% the NRC requirements for the 5- to 45-lb pig, UNL = University of Nebraska vitamin/mineral mix.
[b]Phase I diets formulated to contain: lysine, 1.35%; Ca, 0.80%; P, 0.70%; Available P, 0.39%; DE (digestible energy, kcal/lb), 1.557.
[c]Phase II diets formulated to contain: lysine, 1.20%; Ca, 0.85%; P, 0.75%; Available P, 0.50%; DE (digestible energy, kcal/lb), 1.547.
[d]Composition shown in table 2.
[e]Supplied per kilogram of diet: retinyl acetate, 4,400 IU; cholecalciferol, 440 IU; α-tocopherol acetate, 24 IU; menadione sodium bisulfite, 3.5 mg; riboflavin, 8.8 mg; d-pantothenic acid, 17.6 mg; niacin, 26.4 mg; vitamin $B_{12}$, 26.4 µg.
[f]Supplied per kilogram of diet: Zn (as ZnO), 128 mg; Fe (as $FeSO_4 \bullet H_2O$), 128 mg; Mn (as MnO), 30 mg; Cu (as $CuSO_4 \bullet H_2O$), 11 mg; I (as $Ca(IO_3) \bullet H_2O$), 0.26 mg; Se (as $Na_2SeO_3$), 0.3 mg.

## Introduction

Cooperative-regional research studies investigating nutrient (e.g., lysine) utilization or management practices often rely on specific station (location) ingredients and/or vitamin/mineral premixes. Because significant variability exist among stations, the following study was conducted to develop a vitamin-trace mineral premix to be used as a common source of nutrients in cooperative projects for the NCR-42 (North Central Regional) committee on swine nutrition. The adequacies of the vitamin-trace mineral premixes (NCR-42 VTMM and the vitamin B-safety pak) were evaluated based on growth responses of weanling pigs. Only the results recorded for the UNL portion of the study are presented. Ultimately this data set/results will be combined with results collected at several other stations and presented collectively.

**Table 2. Composition of NCR-42 VTMM and B-safety pak.**

| Vitamin/Mineral | Units/lb | Amount/lb of VTMM | Amount/lb of B Safety Pak |
|---|---|---|---|
| A | IU | 338,800.00 | 0.00 |
| D | IU | 33,880.00 | 0.00 |
| E | IU | 1,452.00 | 0.00 |
| K | mg | 110.00 | 0.00 |
| Biotin | mg | 0.00 | 11.00 |
| Choline | mg | 0.00 | 66,000.00 |
| Folacin | mg | 0.00 | 66.00 |
| Niacin | mg | 2,420.00 | 0.00 |
| Pantothenic Acid | mg | 726.00 | 0.00 |
| Riboflavin | mg | 484.00 | 0.00 |
| Thiamin | mg | 0.00 | 220.00 |
| $B_6$ | mg | 0.00 | 220.00 |
| $B_{12}$ | mg | 2.90 | 0.00 |
| Copper | mg | 145.20 | 0.00 |
| Iodine | mg | 30.80 | 0.00 |
| Iron | mg | 3751.00 | 0.00 |
| Manganese | mg | 0.00 | 0.00 |
| Selenium | mg | 24.20 | 0.00 |
| Zinc | mg | 12,100.00 | 0.00 |

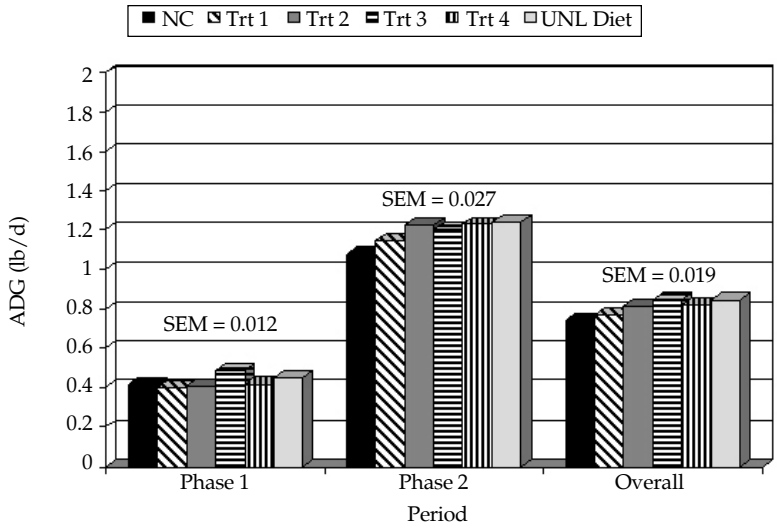
## Materials and Methods

### *Experimental design*

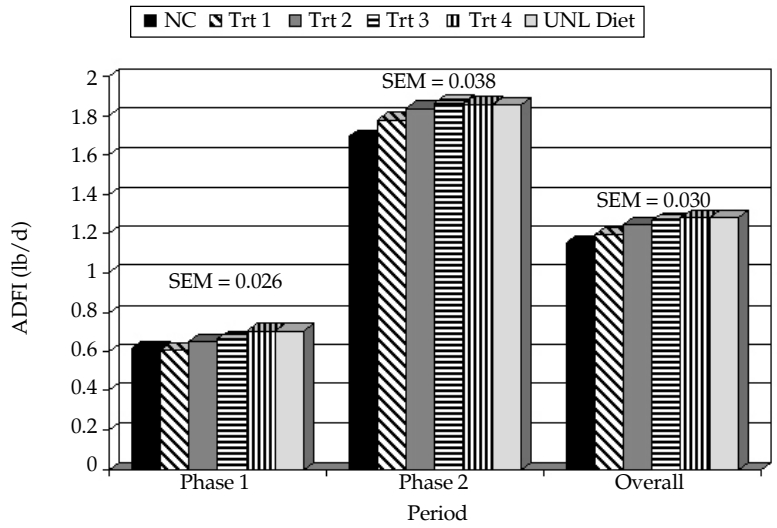
Seventy-two pigs were allotted based on initial weaning weight and litter-of-origin, and randomly assigned to one of six dietary treatments. There were three replications per treatment and four pigs per pen. Pigs were weaned at 18 to 23 days of age with an average initial weight of 11.9 lb. At the conclusion of the 28-day trial, the average weight was 34.2 lb. The trial was divided into two 14-day phases.

The six treatments included (Table 1): 1) negative control (NC), common nursery diet with vitamins at minimum level (0% of NRC 1998 requirements for 5 to 45 lb pigs); 2) treatment 1 (VTMM1X), common nursery diet with vitamin-trace mineral mix (NCR-42 VTMM) added at 100% (1X) of NRC 1998 requirements for 5 to 45 lb pigs; 3) treatment 2 (VTMM3X), common nursery diet with NCR-42 VTMM added at 300% (3X) of NRC 1998 requirements for 5 to 45 lb pigs; 4) treatment 3 (VTMM 1X/B 1X), common nursery diet with NCR-42 VTMM added at 100% and B-safety pak

a)




b)




c)

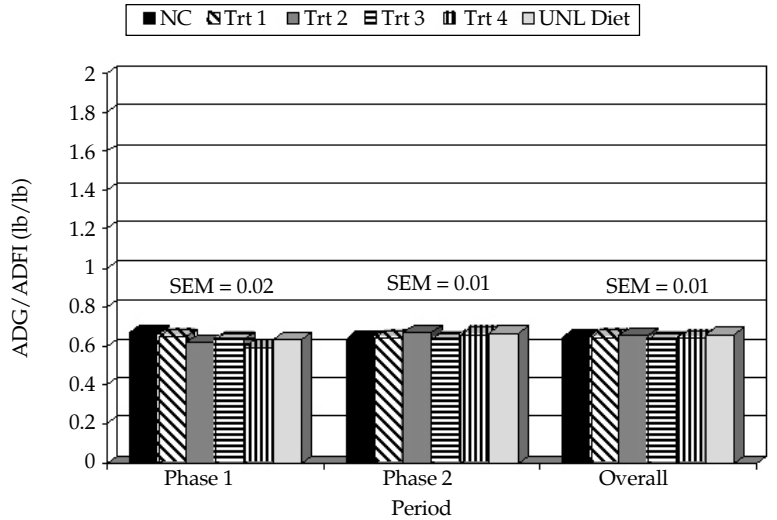



**Figure 1. Phase I, phase II, and overall responses of 12 to 34 lb weanling pigs. a) ADG (average daily gain), b) ADFI (average daily feed intake), c) ADG/ADFI (feed efficiency). NC = negative control (common nursery diet with VTMM at 0% of NRC 1998 requirements for 5 to 45 lb pigs), Trt 1 (common nursery diet with VTMM at 100% of NRC 1998 requirements for 5 to 45 lb pigs), Trt 2 (common nursery diet with VTMM at 300% of NRC 1998 requirements for 5 to 45 lb pigs), Trt 3 (common nursery diet with VTMM at 100% and B-Safety Pak at 100% of NRC 1998 requirements for 5 to 45 lb pigs), Trt 4 (common nursery diet with VTMM at 300% and B-Safety Pak at 300% of NRC 1998 requirements for 5 to 45 lb pigs), UNL Diet (common nursery diet with University of Nebraska vitamin/mineral mix).**

added at 100% of NRC 1998 requirements for 5 to 45 lb pigs; 5) treatment 4 (VTMM 3X/B 3X), common nursery diet with NCR-42 VTMM added at 300% and B-safety pak added at 300% of NRC 1998 requirements for 5 to 45 lb pigs; 6) UNL, common nursery diet with UNL standard vitamin-trace mineral premixes (all of the diets had trace minerals added at 100% of the NRC 1998 requirements for 5 to 45 lb pigs). The NCR-42 B-safety pak included: biotin, choline, folacin, thiamin and vitamin $B_6$ which were excluded in the NCR-42 VTMM premix. (Table 2). Phase I diets contained 1.35% lysine, 0.80% calcium and 0.70% phosphorus. Phase II diets contained 1.20% lysine, 0.85% calcium and 0.75% phosphorus.

*Statistical analysis*

Data were analyzed as a completely randomized block design using the PROC MIXED procedure of SAS. The main effect of the statistical model was dietary treatment. Pen was the experimental unit used for analyses.

*Live animal care and measurements*

Pigs had ad libitum access to feed and water throughout the experiment. Pigs and feeders were weighed weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI). Heat lamps and mats were utilized during phase I and removed for phase II.

## Results and Discussion

Figures 1a-c show the growth criteria responses to dietary treatments. Due to illness during the first week of the trial, one pen receiving treatment 3 was excluded from the data analysis. There were no significant statistical differences ($P > 0.10$) for ADG, ADFI or feed efficiency among treatments

*(Continued on next page)*

(treatment main effect) during phase I, II and the overall experimental period. However, there were numerical increases in ADG, ADFI and feed efficiency with the additions of the VTMM premix and B-safety pak. Increases in ADG and ADFI were observed as the VTMM premix was added at 100% of the NRC 1998 requirements for 5 to 45 lb pigs (ADG: NC = 0.744 lb/d, trt 1 = 0.770 lb/d; ADFI: NC = 1.152 lb/d, trt 1 = 1.194 lb/d). Numerically, ADFI and ADG were maximized at the 300% premix addition (ADG = 0.822 lb/d, ADFI = 1.281 lb/d). Pigs receiving the UNL diet performed equal to or slightly greater than pigs receiving treatment 4 (VTMM 300%, B-safety pak 300% of the NRC 1998 requirements for 5 to 45 lb pigs). Feed efficiency (ADG/ADFI) was improved with the addition of the VTMM premix at 300% of the NRC 1998 requirements for 5 to 45 lb pigs (ADG/ADFI = 0.641). Overall, pigs receiving higher concentrations of the VTMM premix and the B-safety pak or the UNL diet had numerically greater ADG and ADFI than pigs receiving the negative control.

**Conclusion**

Overall, there were no significant differences in ADG, ADFI or feed efficiency when adding supplemental vitamins to the diet. However, there were numerical increases in ADG and ADFI as the supplemental premixes were added to the diet. These numerical differences suggest that growth performance is increased as the VTMM and B-safety pak premixes are supplemented to the diet. In addition, results suggest that the concentration of vitamins/minerals used in diets at the University of Nebraska is adequate given that the pigs consuming this diet performed as well as those consuming other dietary treatments. Data from other stations and data from this trial will be combined in order to form premixes with concentrations sufficient to support maximal growth performance. Collectively, these results will help identify vitamin and mineral premixes that can be used in future multi-site cooperative swine nutrition projects.

[1]Laura R. Albrecht is a graduate student, Robert L. Fischer is a graduate student and research technologist, and Phillip S. Miller is a professor in the Department of Animal Science.

# Incidence and Inheritance of Splayleg in Nebraska Litter Size Selection Lines

**Justin. W. Holl**
**Rodger K. Johnson[1]**

**Summary and Implications**

*Incidence of abnormalities at birth is low in most populations, but accounts for a significant proportion of preweaning deaths. Splayleg pigs (SL) is the most common defect in newborn pigs and a high percentage of SL pigs die before weaning. In research at other institutions, SL incidence was associated with the Landrace breed and with large litters; however, a genetic association with litter size was not demonstrated. The University of Nebraska selection lines originated from a Landrace-Large White composite population and have been selected for 22 generations for increased litter size. These lines provided an excellent resource for the objectives of this study, which were 1) to identify traits associated with the SL condition, 2) to estimate genetic parameters for SL, and 3) to estimate the correlated response in incidence of SL to selection for increased litter size. Variables associated with the SL condition were sex, line, generation, line by generation interaction, birth weight, dam's number of live pigs born, dam's number of nipples, dam's age at puberty, dam's embryonic survival, and inbreeding of the dam. Boars were 234% more likely to display SL than gilts ($P < 0.01$). Decreased birth weight was associated with an increase in likelihood of SL ($P < 0.01$). The percentage of SL pigs increased as litter size increased ($P < 0.01$). Increased incidence of SL occurred in litters by gilts that reached puberty at younger ages ($P < 0.01$) and that had fewer nipples ($P < 0.05$). Decreased embryonic survival to d 50 of gestation also significantly increased the probability of SL pigs in the litter ($P < 0.05$). Inbreeding of the pig did not significantly affect the incidence of SL, but the likelihood of SL increased with dam's inbreeding ($P < 0.05$). Estimates of 0.16 for maternal heritability and 0.32 for genetic correlation between number of pigs born alive and SL were obtained. Selection to increase litter size was not associated with genetic potential of individual pigs to be born with SL. However, selection for increased litter size indirectly increased the genetic potential for sows to create a uterine environment more likely to produce litters with SL pigs. The SL condition should be treated as a trait of the sow, rather than the individual piglet.*

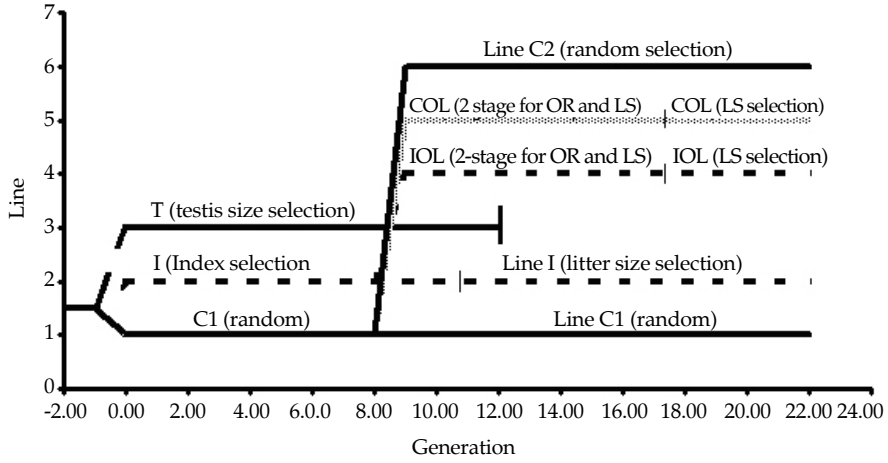



**Figure 1. Evolution of the NE selection lines: C1 & C2 = random selection lines, I = Index selection line, COL & IOL = 2-stage selection lines for ovulation rate (OR) and litter size (LS).**

## Introduction

Splayleg (SL), also commonly called spraddle leg, is the most common birth defect in pigs and survival of pigs with SL is approximately 50%. The incidence of SL pigs has been reported to be greater in Landrace than in other breeds and increased incidence of SL has been associated with larger litters.

Four selection lines, three selected for litter size and its component traits and one selected for testis size, were created from a Large White–Landrace composite population with the objective to improve litter size. Selection for litter size and its components effectively increased litter size in three lines. Testis size increased approximately 50% in 10 generations of selection, but correlated response in litter size was not significant.

Incidence of SL and data on other traits were collected on pigs in these selection lines and their randomly selected controls and analyzed with the objectives of 1) to identify variables affecting the incidence of SL, 2) to estimate genetic parameters for SL, and 3) to estimate correlated responses in incidence of SL to litter size and testis size selection.

## Methods

*Population*

Development of the Nebraska selection lines is illustrated in Figure 1. A base, composite population of Large White and Landrace was formed in 1979. After two generations of random mating, a line selected for increased index of ovulation rate and embryonic survival (Line I), a control line (C1), and a testis size selection line (Line T) were created and selection began. Line I was selected for an index of ovulation rate and embryonic survival to increase litter size. Line C1 was randomly selected. Line T was selected for increased weight of testes; weight was predicted from testes lengths and widths measured at 150 d of age. Twelve generations of selection were practiced in Line T and the line was terminated.

Index selection in Line I was terminated after 11 generations and selection for increased number of fully formed pigs per litter was practiced from Generations 12 through 14. During Generations 15 to 19, between litter selection for number of live pigs born and within litter selection for increased birth weight was practiced in Line I and selection during Generations 20 to 22 was for increased number of live pigs born and within litter selection for increased growth rate, decreased backfat and increased *longissimus* muscle area. Lines I, T and C1 were contemporary in a group that farrowed each year during July and August.

Selected, Generation 8 parents in Lines C1 and I were re-mated within line after females produced their first litter to create a control line and two lines in which two-stage selection for ovulation rate and number of fully formed pigs was practiced. Pigs in Line C1 second parity litters were randomly assigned within litter to a control line (designated Line C2) or to a two-stage selection line (Line COL). The Line I litters were the base for the other two-stage selection line (Line IOL). Lines IOL, COL, and C2 were contemporary and farrowed at a six-month interval to lines I and C1. Generations in Lines IOL, COL, and C2 will be referenced from the initiation of selection in the base composite population. Selection in Lines IOL and COL during Generation 17 for litter size and birth weight, and subsequent selection for litter size, growth, backfat and *longissimus* muscle area was as described above for Line I.

*Data*

Within 24 hours of birth, sex, birth weight (BWT), number of nipples (NN) and birth abnormalities were recorded. Age at puberty (AP) was recorded in gilts of Lines I and C1 from Generation 2 through Generation 15, in Line T through Generation 12 and in gilts of Lines IOL, COL and C2 through Generation 16. Ovulation rate (OR) was recorded in gilts of Lines I and C1 through Generation 11, and in gilts of Lines IOL, COL and C2 through Generation 16. Embryonic survival (ES), the

*(Continued on next page)*

proportion of embryos at day 50 to ovulation rate, was recorded in gilts of Lines I, and C1 from Generations 1 to 11. Age at farrowing (AF) was recorded in all females with litters and number of fully formed pigs (FF), number of mummified pigs (MUM), number of stillborn pigs (SB), and number of pigs born alive (BA) were recorded in all litters. The inbreeding coefficient of each pig was calculated.

A total of 37,673 records on pigs born alive were used. Table 1 shows the number of pigs born alive, number of SL pigs, number of gilts with AP, OR, and ES records by line and generation since initiation of selection in 1981. Splayleg pigs were not recorded in Generation 0 or in Generation 9 in Lines IOL, COL, and C2.

*Statistical procedures*

Birth weight and the SL condition were considered to be traits of the pig, but modeled with a maternal component. All other traits were considered as traits of the dam (i.e. dam's age at puberty, DAP, dam's age at farrowing, DAF, etc.). Incidence of SL, coded as 0 or 1 in individual pigs, was analyzed with a generalized linear model to determine variables associated with it. If associations between SL and other traits were significant (P < 0.10), variances, direct and maternal heritabilities, genetic correlations and breeding values were estimated with linear animal models.

**Table 1. Number of observations for pigs born alive (BA), splayleg pigs (SL), age at puberty (AP), ovulation rate (OR), and embryonic survival (ES) by contemporary group (CG) and generation.**

| | CG1[a] | | | | | CG2[a] | | | |
|---|---|---|---|---|---|---|---|---|---|
| Generation[b] | BA | SL | AP | OR | ES | BA | SL | AP | OR |
| 1 | 1409 | 50 | — | 150 | 150 | — | — | — | — |
| 2 | 1171 | 53 | 255 | 157 | 155 | — | — | — | — |
| 3 | 1202 | 46 | 278 | 171 | 171 | — | — | — | — |
| 4 | 1175 | 62 | 282 | 171 | 171 | — | — | — | — |
| 5 | 1189 | 29 | 326 | 186 | 165 | — | — | — | — |
| 6 | 1173 | 26 | 288 | 151 | 151 | — | — | — | — |
| 7 | 1233 | 83 | 290 | 186 | 186 | — | — | — | — |
| 8 | 1200 | 51 | 286 | 194 | 194 | — | — | — | — |
| 9 (1) | 1152 | 53 | 267 | 177 | 177 | — | — | — | — |
| 10 (2) | 1154 | 84 | 377 | 175 | 175 | 1164 | 49 | 244 | 193 |
| 11 (3)[c] | 1299 | 80 | 160 | 210 | 210 | 1407 | 53 | — | — |
| 12 (4) | 1306 | 58 | 145 | — | — | 1179 | 41 | 258 | 180 |
| 13 (5) | 921 | 40 | 160 | — | — | 1195 | 79 | 232 | 210 |
| 14 (6) | 1218 | 22 | 159 | — | — | 1179 | 47 | 241 | 236 |
| 15 (7) | 1503 | 49 | 172 | — | — | 1224 | 55 | 236 | 225 |
| 16 (8) | 1350 | 43 | — | — | — | 1295 | 94 | 247 | 240 |
| 17 (9) | 777 | 20 | — | — | — | 1085 | 50 | — | — |
| 18 (10) | 706 | 16 | — | — | — | 1393 | 83 | — | — |
| 19 (11) | 696 | 25 | — | — | — | 1408 | 70 | — | — |
| 20 (12)[d] | 1075 | 13 | — | — | — | 298 | 3 | — | — |
| 21 (13)[d] | 835 | 17 | — | — | — | 351 | 9 | — | — |
| 22 | 751 | 10 | — | — | — | — | — | — | — |
| Total | 24495 | 930 | 3445 | 1928 | 1905 | 13178 | 633 | 1622 | 1407 |

[a]CG1 = Lines C1, I, and T; CG2 = Lines IOL, COL, and C2.
[b]Generations from initiation of selection in composite founder population. Numbers in parentheses indicate generations of selection practiced in CG2 since diverging from CG1.
[c]Age at puberty and ovulation rate were not measured in Generation 3 gilts in CG2.
[d]Number of observations in CG2 are from Line C2.

**Table 2. Percentage increases in likelihood of splayleg for significant effects, expressed as changes from the population mean, in logistic regression models**

| Trait[a] | Effect/change | Percentage increase[b] |
|---|---|---|
| Sex | Male vs female | 223.6 ** |
| BWT | -10 g | 1.5 ** |
| DBA | +1 pig | 2.9 ** |
| DNN | -1 nipple | 4.6 * |
| DAP | -1 d | 0.5 ** |
| DES | -10% survival | 11.5 * |
| DINB | +1% inbreeding | 1.5 * |

[a]BWT = individual birth weight, DBA = dam's number of pigs born alive, DNN = dam's number of nipples, DAP = dam's age at puberty, DES = dam's embryonic survival at 50 d, DINB = dam's inbreeding coefficient.
[b]A decrease of 10 g from mean BWT (.022 lb) increased the likelihood of splayleg 1.5%, a decrease of 20 g (.044 lb) increased the likelihood by $100*[(1+1.5/100)^2 -1] = 3.02\%$, a 30 g decrease (.066 lb) increased the likelihood by $100*[(1+1.5/100)^3 -1] = 4.57\%$, etc.
*P < 0.05.
**P < 0.01.

## Results and Discussion

The incidence of SL in Lines I, C1 and T across generations is shown in Figure 2. The incidence was consistently greatest in Line T. Until Generation 9, the incidence was less in Line I than Line C1, but after Generation 10, the incidence in Line I relative to Line C1 tended to increase.

The incidence of SL in Lines IOL, COL and C2 is shown in Figure 3. After Generation 10, the difference in percentage of pigs born SL in Line IOL and in Line C2 was 2.6%. The incidence of SL pigs tended to be greater in Line COL than in Line C2 after Generation 10.

Percentage increases in the likelihood of the SL condition for traits significantly associated with it in logistic regression models are in Table 2. Incidence of SL in males was 223.6% greater than in females (P < 0.01). Regression coefficients on continuous variables in the model are expressed as the percentage increase in the likelihood of SL per change in the trait as a deviation from the population mean. For example, the logistic regression of incidence of

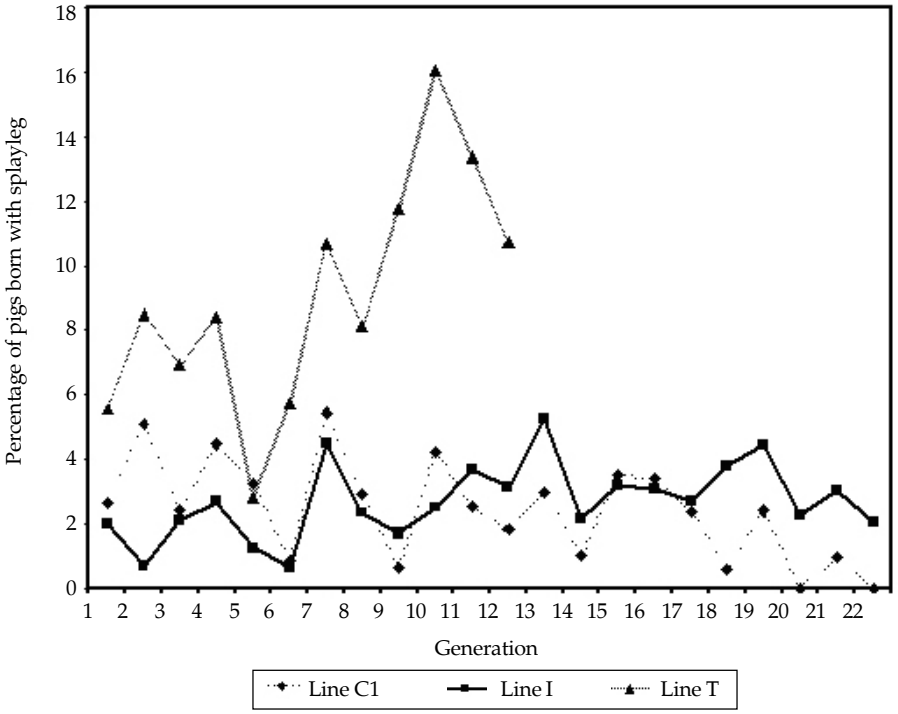



**Figure 2. Percentage of pigs born splayleg (SL) by generation in Lines C1, I and T (see footnote to Table 3 for description of lines).**

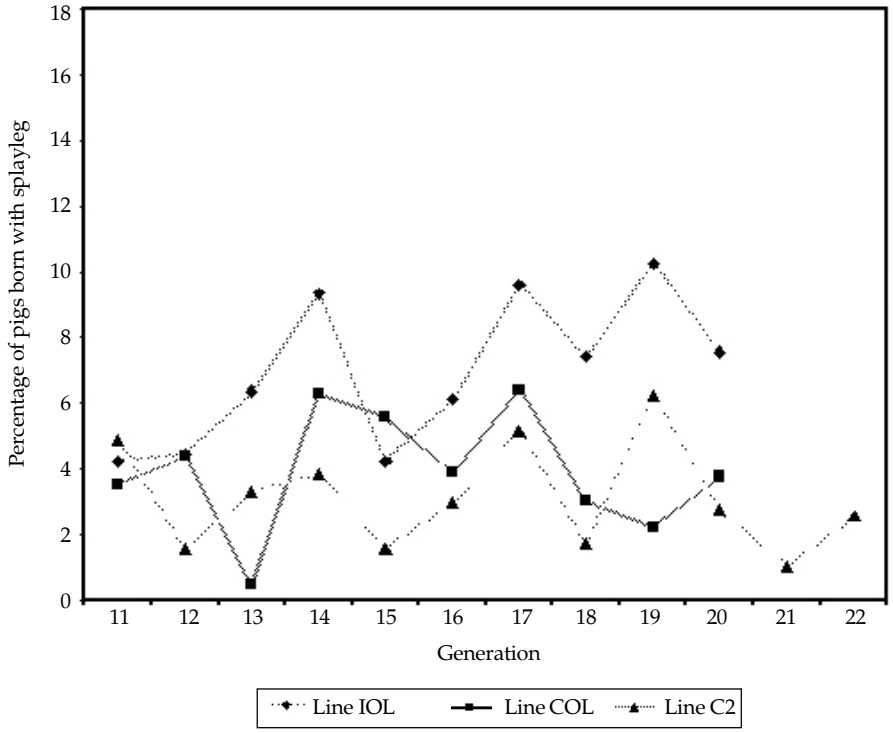



**Figure 3. Percentage of pigs born splayleg (SL) by generation in Lines IOL, COL and C2 (see footnote to Table 3 for description of lines).**

SL per decrease of 10 g (.022 lb) in BWT was 0.015, interpreted as an increase of 1.5% in the likelihood of SL for a deviation of –10 g from the population mean BWT. Additional deviations from the population mean produced exponential rather than linear increases in the likelihood so that a decrease of 20 g (.044 lb) in BWT increased the likelihood of SL by $100*[(1+1.5/100)^2 - 1] = 3.02\%$, and a 30 g (.066 lb) decrease increased the likelihood by $100*[(1+1.5/100)^3 - 1] = 4.57\%$, etc.

Five traits of the dam significantly affected the likelihood of SL pigs. The percentage of SL pigs increased as litter size increased ($P < 0.01$). In addition, gilts that reached puberty at younger ages ($P < 0.01$) and gilts that had fewer nipples ($P < 0.05$) farrowed litters with a greater incidence of SL pigs. However, age at farrowing did not affect the incidence of SL pigs. Although there was variation in age at puberty, the breeding period was approximately the same time each year for each contemporary group. Gilts were mated to farrow at an average age of one year and in those generations in which age at puberty was recorded, only 3.5% of the gilts were mated at their pubertal estrus or their first post-pubertal estrus. Consequently, age at puberty and age at farrowing are not similar traits. Decreased embryonic survival to 50 days also increased ($P < 0.05$) the probability of SL pigs in the litter. Inbreeding of the pig did not affect the incidence of SL ($P > 0.10$), but the likelihood of the SL condition increased with dam's inbreeding ($P < 0.05$). In other research, it also was found that sows with shorter gestation lengths have litters with greater incidence of SL pigs.

Maternal genetic effects on incidence of SL were more than twice as great as direct genetic effects of the pig. Direct heritability, the proportion of the variation due to effects of the pig's genes, was 0.07; maternal heritability, the proportion of the variation due to effects of the dam's genes, was 0.16. Phenotypic correlations of SL with other traits were close to zero. However, a correlation of 0.32 between maternal genetics for SL and direct

*(Continued on next page)*

genetic effects for BA was found.

Annual direct and maternal genetic and phenotypic trends are presented in Table 3. These are estimates of the average observed changes per generation. In addition, genetic parameters were estimated from the data and used to calculate predicted genetic changes in each line to compare them with realized responses. Predicted responses in incidence of SL were calculated from estimates of the responses in litter size in each line and the correlation between direct genetic effects for number of pigs born alive and maternal genetic effects for SL pigs. Predicted maternal genetic responses per generation in percentage units were 0.159, 0.323, -0.068, 0.420, 0.446, and 0.146 for Line C1, I, T, IOL, COL, and C2, respectively. Predictions were relatively close to observed responses in all lines except I and T. Index selection was discontinued in Line I at Generation 12 and selection on number of fully formed pigs was practiced thereafter. From Generation 12 to Generation 22, the realized trend in maternal genetic merit was 0.339 + 0.014 percentage units, which is similar to the predicted trend. While index selection was practiced, maternal genetic trend in SL was suppressed. However, after index selection, realized maternal genetic trend was faster than predicted. Differences between predicted and realized responses in certain lines could also be chance associations due to genetic drift. The large variation in direct genetic trend among lines (Table 3) indicated either no correlated response to litter size selection or genetic drift cancelled the effect of selection.

**Table 3. Regression coefficients (b) and standard errors (se) of line genetic and phenotypic values of incidence of splayleg pigs in percentage units[a] on generation number.**

| | Direct genetic | Maternal genetic | Phenotypic |
|---|---|---|---|
| Line[b] | b + se | b + se | b + se |
| C1 | -0.274 + 0.004 | 0.188 + 0.005 | -0.158 + 0.029 |
| I | -0.003 + 0.003 | 0.106 + 0.004 | 0.067 + 0.027 |
| T | 0.243 + 0.014 | 0.527 + 0.024 | 0.777 + 0.144 |
| IOL | 0.121 + 0.012 | 0.508 + 0.019 | 0.472 + 0.123 |
| COL | -0.273 + 0.009 | 0.383 + 0.015 | -0.001 + 0.097 |
| C2 | 0.086 + 0.008 | 0.113 + 0.012 | -0.042 + 0.079 |

[a]Change in incidence of SL per year, i.e., the phenotypic regression for C1 of -0.158 is a decrease in incidence of SL of .158% per year.
[b]C1 = Randomly selected control line 1, I = Index selection line, T = testis size selection line, IOL = line derived from Line I and subsequently selected for ovulation rate and litter size, COL = line derived from line C1 and subsequently selected for ovulation rate and litter size, and C2 = random selection line 2 derived from line C1.

Splayleg is a heritable trait, subject to both direct and maternal genetic variation. The maternal component is correlated genetically with dam's genetic merit for litter size. Selection to increase litter size is not expected to affect the genetic potential of individual pigs to be born with SL. However, increased genetic potential of sows to create a uterine environment causing SL may occur with selection for increased litter size.

[1]J. W. Holl is a graduate student and R. K. Johnson is a professor in the Department of Animal Science.

# How Big is "Big Enough" to Make a Living in Pork Production?

**Allen Prosch**[1]

**Summary and Implications**

*The size of pork production units in Nebraska increased dramatically from 1989 to 2002. In 1989, producers who marketed less than 1,000 hogs per year held 61% of Nebraska's hog inventory. By 2002, only 23% of Nebraska's hogs were held by those producers. Many decisions affect the size of a swine production unit. Basic to any decisions on size is whether the enterprise is profitable and can provide a reasonable living to those owning and working in the unit. Data from the Nebraska Swine Enterprise and Records Analysis program suggests that Nebraska farrow-to-finish producers needed to increase the size of their herds by 51% or half again as large to maintain the level of income over living for the period 1989 to 2002. During this period, the average Nebraska swine enterprise grew larger than predicted if growth was in response to maintain family living expenses. While maintaining a living may be one reason for growth, it appears there are other important drivers of growth in production unit size.*

**Introduction**

Iowa State University researchers found that farrow-to-finish pork producers in Iowa had a slightly profitable 10-year period from 1994 to 2003, with returns averaging $0.21/head. This information suggests that pork producers could not make a

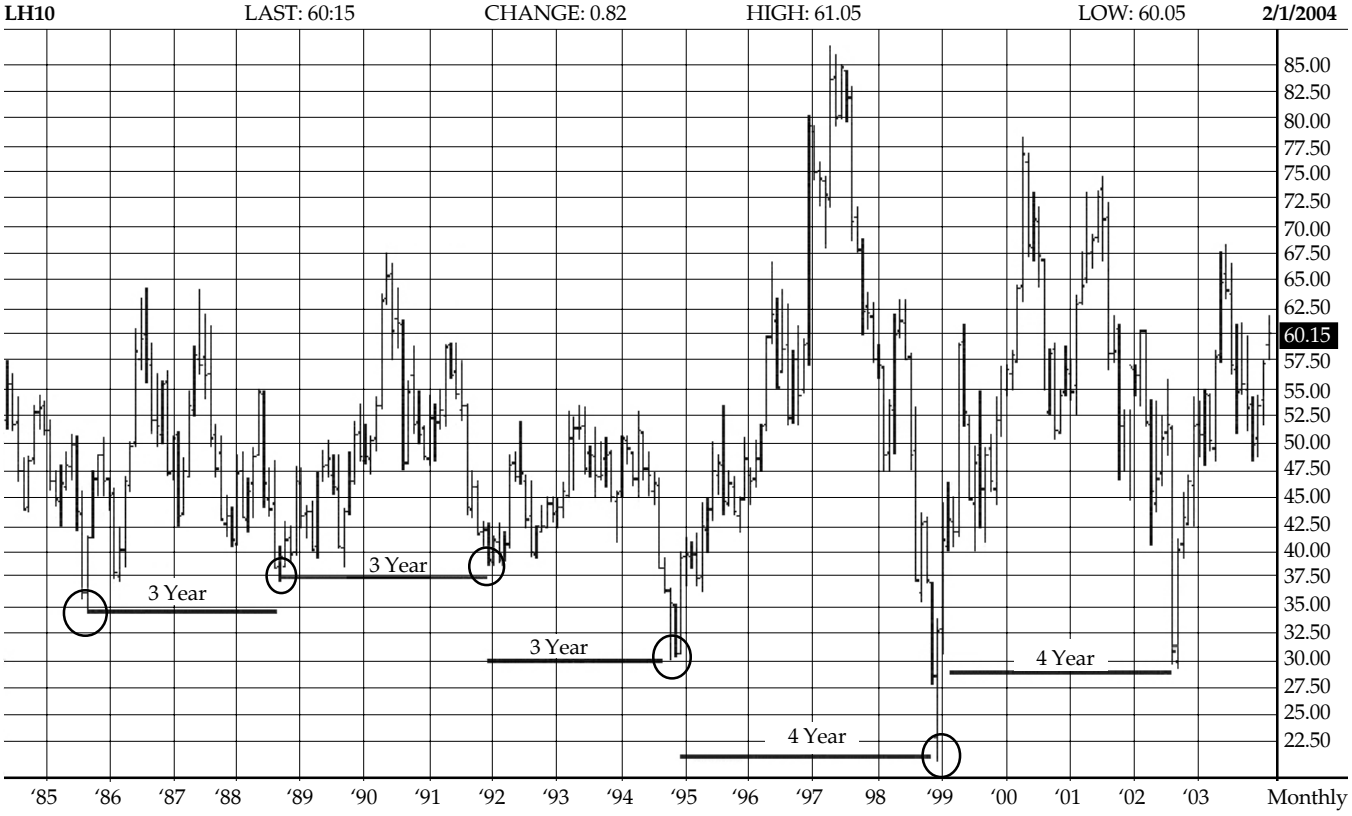



**Figure 1. Chicago Mercantile Exchange Lean Hog Carcass Futures contract data.**

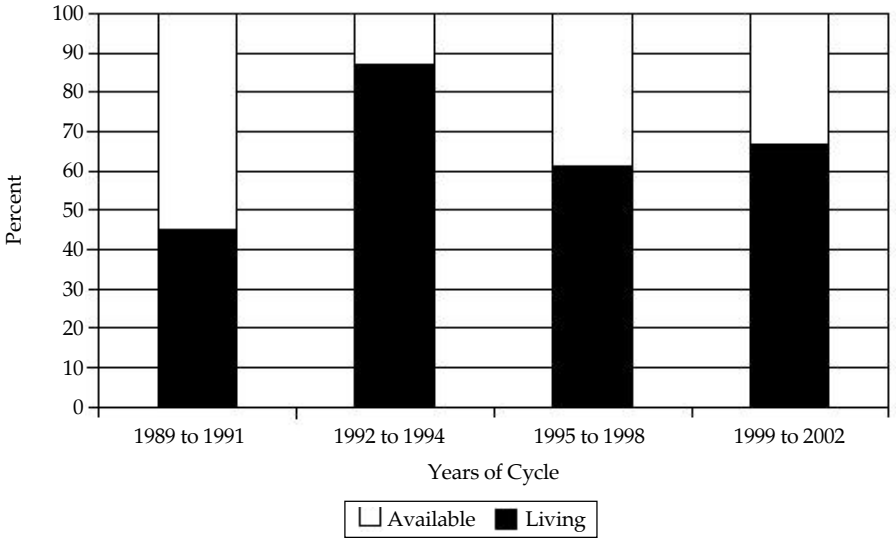



**Figure 2. Percent of available dollars needed for living expenses.**

reasonable living and, therefore, many would discontinue their operations. Those that remained would need to expand to provide a reasonable living. As operations expanded, economies of scale would drive some growth. This paper examines the production characteristics of producers in the *Nebraska Swine Enterprise and Records Analysis* (NSER&A) program and evaluates their ability to generate a family living from 1989 to 2002.

## Methods

To examine the growth determinants, data from the NSER&A and the Nebraska Farm Business Association (NFBA) were used to analyze whether a farrow-to-finish swine enterprise of modest size still can generate sufficient profits to support family living expenses. Family living expenses reported by the NFBA for 1989 to 2002 were compared to U.S. census data for household income in Grand Island, Neb. Reported NFBA farm living expenses are very similar to average household incomes in this non-farm community. While NSER&A data includes information on the high profit one-third, low profit one-third and overall average, data for the average of all producers were used in the comparisons.

The NSER&A program ended

*(Continued on next page)*

in 1997 due to declining enrollment. Results from 1998 through 2002 were calculated using yearly feed cost corrections and annual average changes in non-feed costs. Productivity was increased at the same annual rate of improvement as in the 1989-1997 period.

NSER&A data contain both paid and unpaid labor costs as an expense item. As a non-cash expense, unpaid labor cost was added back to the total dollars available. These funds could be used to provide a living when comparing income versus living expenses.

In the NSER&A data, interest costs were charged on all operating capital (10%) and all fixed capital (12%). Interest costs were added back to available income when comparing income versus living expenses. This is done to provide a comparison of the true earnings of the operation regardless of financing.

*Hog cycles*

Hog prices remain cyclical, generally cycling in a 3- to 4-year period. Cycle lows occurred in 2002, 1998 and 1994 (four year cycles), and again in 1991, 1988 and 1985, (three year cycles) (Figure 1). Comparing the ability of an operation to generate available income to provide a family living through an entire cycle of highs and lows reduces the single-year effect and helps determine if producers are able to generate an adequate living over time.

*Producer productivity*

From 1988 to 1997, producers in the NSER&A increased the number of pigs sold per sow per year from 13.0 to 16.7. In 1997, the high profit one-third (top one-third) sold 19.4 pigs per sow per year.

This study examines profit from a breeding herd of 125 sows from 1990 to 2002. It was assumed that herd produced 19.4 pigs for sale per sow per year in 2002, a level achieved by the top one-third in 1997.

*Living costs*

In 1989, the NBFA reported average family living expense was $25,944 before taxes. By 2002, this had increased 48% to $38,341. As a comparison to non-farm families, median household income in Grand Island, Neb. was $25,019 in 1989 and $36,044 in 2002, a 44% increase. In 1989 NFBA reported living was 3.7% higher than the household income reported at Grand Island. By 2002 that had increased to 6.4%. The data suggests the amount and the rate of increase in living expense (NFBA) and household income (Grand Island) were similar for farm and non-farm families in Nebraska.

**The Ability to "Make a Living"**

During the first cycle from 1989 to 1991, NSER&A results suggest a 125-sow farrow-to-finish enterprise would have used 45% of the cash it generated to pay for family living (Figure 2). During the fourth cycle, 1999 to 2002, that enterprise would have used 67% of generated cash to pay family living.

These results suggest that a producer with 125 sows could have had profits sufficient to pay more than living expenses over the 14 years included in the four cycles. But producers would have needed to increase the size of their swine enterprise if they wanted to maintain the same total margin in cycle four as they had in cycle one.

Farrow-to-finish producers would have had to increase the existing 125 sow herd by 64 sows or 51% which would increase marketing to 3,659 hogs per year to maintain the margins enjoyed during the first cycle. The need to generate all family living expenses does not explain the large increases in swine production unit sizes in Nebraska.

---

[1]Allen Prosch is the Pork Central Coordinator at the University of Nebraska. References are available by request from the author.

# Heating Systems for Wean-to-Finish Facilities

**Michael C. Brumm**
**Richard R. Stowell**
**Sheryl L. Colgan[1]**

**Summary and Implications**

*Research was conducted to assess the effects of the type of zone heater and floor mat used in a wean-to-finish facility on pig performance and operating cost. Gas-fired brooder heaters were compared to 250W heat lamps and farm-cut wood sheathing was compared to commercial (unheated) rubber floor mats for a 21-day post-weaning period. There was no effect of heating system or mat type on pig performance, either during the 21-day period immediately post-weaning or to slaughter. Black globe temperatures near the pig zone were slightly higher for the propane-fired heaters compared to the heat lamps, most likely due to the method and temperature settings used to control the gas flow to the heaters. Black globe temperatures were slightly higher for the wood mats versus the rubber mats, most likely due to the difference in infrared energy absorption between the black mats and the natural wood colored mats. When amortized over a seven-year payback period, total operating expense for the heat lamps and propane brooders was estimated to be similar based on 25 pigs per pen and 20 pens per propane control module. These results suggest that both types of heating systems are effective in maintaining an acceptable temperature zone for weaned pigs. They also suggest little difference in performance due to the type of floor mat under the zone heating device. The selection of heating system and floor mat material can be based on reasons other than pig performance.*

**Introduction**

Wean-to-finish facilities now comprise 15% or more of all grow-finish facilities in the United States. With the rapid adoption of wean-to-finish technology comes the question – what is the best zone heating system for these facilities? For a majority of producers, the definition of "best" includes both pig performance and investment/operating cost of the zone heating system.

Heat lamps are a commonly used radiant heat source for zone heating. While inexpensive to install, they are criticized for their high operating expense that includes frequent replacement of bulbs. Propane brooders are fairly expensive to install but have a relatively low operating cost.

In wean-to-finish facilities, producers are using mats on top of the cement slats. These mats serve to reduce drafts through the slats and as a feeding platform for those that hand-feed pigs for a period of time following weaning to encourage feed intake. Rubber mats can be relatively expensive to purchase, and they must be washed, disinfected and stored between uses. In addition, in large pen facilities, large mats are heavy and often require two people to remove from a pen. Black rubber mats often have a "feed saver" lip that reduces the pig's ability to nudge feed from the mat. The black color also absorbs radiant heat.

An alternative to the rubber mats that many are using is plywood or other wood products. The advantage of wood is that it is usually burned after a single use, eliminating the need to wash, disinfect and store the mat. In large pen situations, if the wood is 1/4 inch material, one person can often remove the mat from the pen. Possible disadvantages of wood include the recurring purchase expense and the possibility of wood chips in the manure storage device if the pigs are allowed to begin playing with the mat prior to removal. While unpainted wood doesn't absorb radiant heat as well as the rubber mat, wood is a good insulator, meaning limited heat is transferred from the sleeping pig to the cement slat under the mat.

This research project was designed to examine the impact of two types of zone heating sources and two types of mat material on weaned pig performance from weaning to slaughter.

**Materials and Methods**

The research project was conducted in a wean-to-finish facility at the Haskell Agricultural

*(Continued on next page)*

Laboratory near Concord, Neb. Crossbred pigs (Danbred NA, Seward, Neb.) were weaned at approximately 17 days of age and transported four hours to the facility on Jan. 21, 2004. The effect on pig performance of two heat sources (propane fired brooder heater vs. 250w heat lamp) and two types of floor mats (3/8 inch oriented-strand board vs. rubber) in a 2 x 2 factorial arrangement of treatments was compared. Details of the heat sources and floor mats were provided in the 2004 Nebraska Swine Report (page 34).

The trial was conducted in a fully slatted, naturally ventilated facility with 16 8 ft x 14 ft pens. Each pen held 15 pigs (7.5 $ft^2$/pig). Each pen had one two-hole FarmWeld wean-to-finish feeder and one wean-to-finish cup drinker. All mats were 41 inches x 41 inches and were located near the feeder along the center aisle of the facility. Treatments were randomly assigned to pens and sex was balanced within pen.

Pigs were weighed weekly for the first four weeks following weaning and at regular intervals thereafter. On day 147 following weaning, 50% of the pigs were sold to slaughter. The remaining pigs were sold on day 161.

From weaning to 45-pound body weight, pigs were fed commercially prepared diets according to a pre-determined feed budget. From 45 pounds to slaughter, they were fed according to the University of Nebraska Swine Nutrition Guide recommendations for pigs with high lean gain potential. Other than the Phase-1 starter diet which was a mini-crumble, all diets were in meal form. Fat additions to the diet varied between 1.5 and 3%.

Air temperature in the facility was maintained with unvented propane-fired space heaters. The sensor for the controller was located in the middle of the facility at approximately 54 inches above the floor. Air temperature was set to be maintained at 76°F the first week after weaning and was decreased 2°F per week for the first three weeks post-weaning.

The mats and zone heating were in place for 21 days following weaning in all pens. At 21 days post-weaning, the mats and zone heating were removed. At that time, the controller for the room heaters was set to maintain 76°F and this setting was reduced 1°F per week until a set point of 62°F was attained. Sprinklers were used for heat relief in May and June, with sprinkling beginning at 80°F.

Electricity and propane usage was recorded daily between 8 and 10 a.m. while the zone heat and mats were used.

The pen of pigs was the experimental unit for statistical analysis. Results were analyzed as a complete random design using a 2 x 2 factorial arrangement of treatments using the GLM procedure of SAS. Death loss and pig removal was analyzed by Chi-squared analysis.

**Table 1. Effect of experimental treatments on pig performance.**

| | Floor mats | | Heater | | | P Values | | |
|---|---|---|---|---|---|---|---|---|
| Item | Rubber | Wood | Lamp | Propane | SEM | Mat x heater | Mat | Heater |
| No. pens | 8 | 8 | 8 | 8 | | | | |
| Pig weight, lb | | | | | | | | |
| Wean | 13.8 | 13.7 | 13.6 | 13.9 | 0.2 | NS[a] | NS | NS |
| d 21 | 29.1 | 28.7 | 28.3 | 29.5 | 0.5 | NS | NS | NS |
| d 147 | 261.9 | 263.6 | 261.7 | 263.8 | 1.9 | NS | NS | NS |
| Final | 275.9 | 274.7 | 274.9 | 275.7 | 1.4 | <0.08 | NS | NS |
| Coefficient of variation of pig weight within pen, % | | | | | | | | |
| Wean | 19.7 | 18.4 | 17.6 | 20.5 | 0.5 | NS | NS | <0.01 |
| d 21 | 23.2 | 24.1 | 24.2 | 23.1 | 1.8 | NS | NS | NS |
| d 147 | 9.4 | 10.0 | 9.8 | 9.6 | 0.7 | < 0.05 | NS | 'NS |
| Average daily gain, lb | | | | | | | | |
| Wean–d 21 | 0.73 | 0.71 | 0.70 | 0.74 | 0.02 | NS | NS | NS |
| d 21–d 147 | 1.85 | 1.86 | 1.85 | 1.86 | 0.01 | NS | NS | NS |
| Wean-final | 1.70 | 1.70 | 1.70 | 1.71 | 0.01 | NS | NS | NS |
| Average daily feed, lb | | | | | | | | |
| Wean–d 21 | 0.97 | 0.91 | 0.90 | 0.97 | 0.04 | NS | NS | NS |
| d 21-d 147 | 4.84 | 4.80 | 4.77 | 4.88 | 0.07 | NS | NS | NS |
| Wean-final | 4.36 | 4.34 | 4.31 | 4.39 | 0.07 | NS | NS | NS |
| Feed:gain | | | | | | | | |
| Wean–d 21 | 1.32 | 1.27 | 1.29 | 1.30 | 0.03 | NS | NS | NS |
| d 21–d 147 | 2.62 | 2.57 | 2.57 | 2.62 | 0.03 | NS | NS | NS |
| Wean-final | 2.57 | 2.55 | 2.54 | 2.58 | 0.03 | NS | NS | NS |
| No. dead/removed | 6 | 6 | 5 | 7 | | | | |

[a]NS = not significant ($P > 0.1$).

## Results and Discussion

The pigs in this experiment were from a PRRS (Porcine Respiratory and Reproductive Syndrome) negative source, and the overall performance was excellent. Causes of death included a strangulated hernia, gastric torsion, ulcer and other miscellaneous causes. There was no effect of experimental treatments on the number of pigs treated or death loss.

There were almost no interactions between heating system and floor mat, so the main effects of heating system and floor mats on pig performance are presented in Table 1. There was no effect of heating system or type of floor mat on pig performance for the

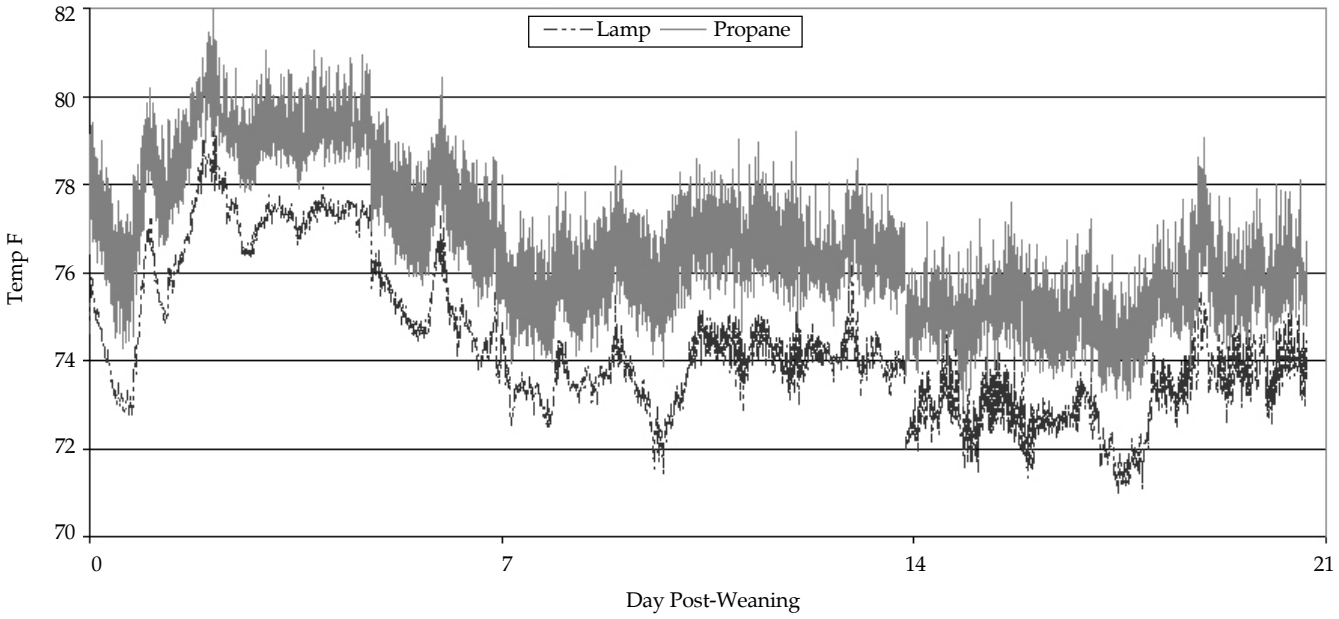



**Figure 1. Black globe temperature by heat source averaged every 10 minutes.**

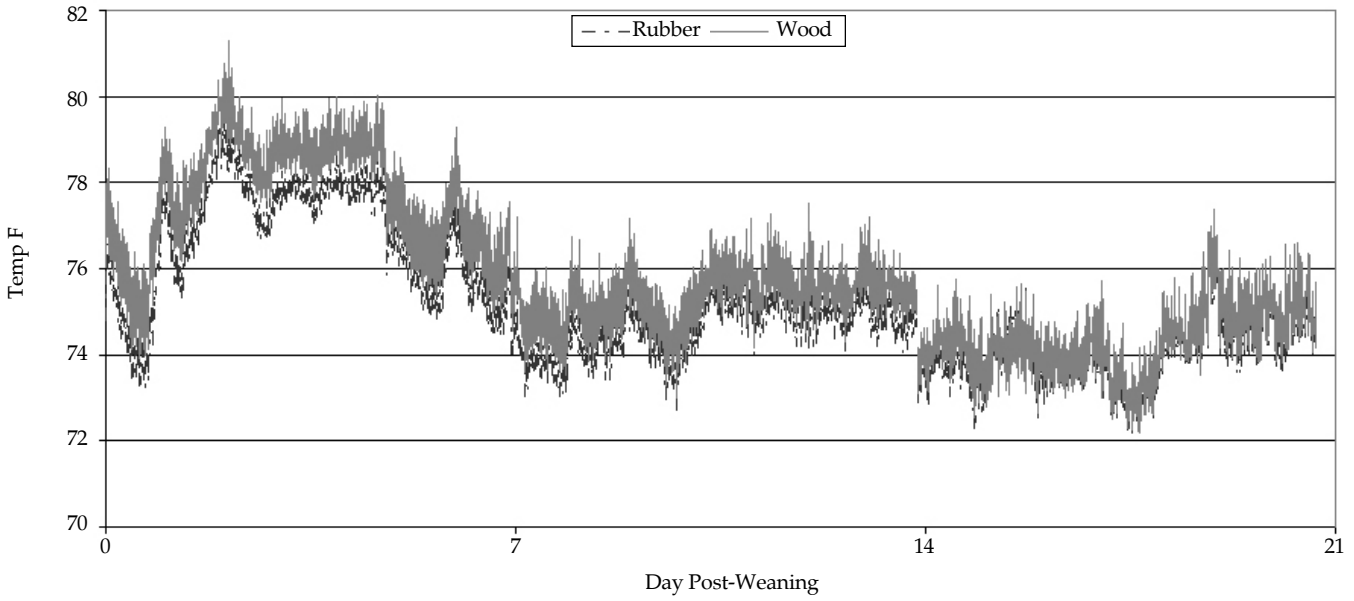



**Figure 2. Black globe temperature by mat type averaged every 10 minutes.**

first 21 days post-weaning. There was no carryover effect of heating system or type of floor mat on pig performance as indicated by the lack of difference in any performance variable for the day 21-147 period or overall.

Black-globe temperatures are presented in Figures 1 and 2 for the heating systems and mat types. Measurement of "black-globe temperature" directly incorporates the effect of radiant heating — the type of heating provided by both zone heating systems. The variation in black-globe temperature for the propane brooders is due to the control system chosen for this heating system. Gas flow to the propane heaters was controlled via a gas manifold linked to an electronic ventilation controller. This controller had a shielded temperature sensor suspended beneath one of the propane brooders. The controller was set to increase gas flow to all eight brooders when this sensor was at 94°F and decrease gas flow at 95°F,

*(Continued on next page)*

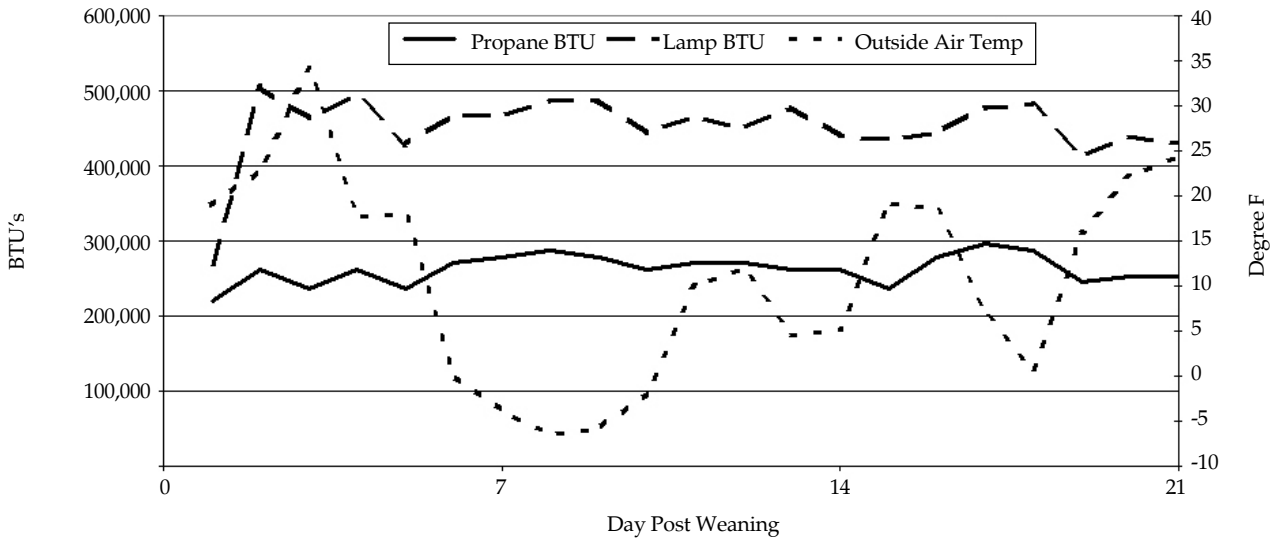



**Figure 3. Daily energy usage (Btu's) for each heating system and 24 hour average outside air temperature.**

**Table 2. Heating system investment costs, 25 pigs/pen.**

| | Lamp fixture ($) | Total unit fixed cost ($) | Number of units (pens) | | Total system fixed cost ($) | System fixed cost per pen ($) | System fixed cost per pig ($) | Useful life N (years) | Annualized fixed cost @ i=8% ($/yr/pig) |
|---|---|---|---|---|---|---|---|---|---|
| Lamps | 10 | 10 | 8 | | 80 | 10 | 0.40 | 7 | 0.08 |
| | 5400 Btu heater & hose & coupler ($) | Total unit fixed cost ($) | Number of units (pens) | Modulating gas valve & regulator ($) | Total system fixed cost ($) | System fixed cost per pen ($) | System fixed cost per pig ($) | Useful life N (years) | Annualized fixed cost @ i=8% ($/yr/pig |
| Propane | 110 | 110 | 8 | 532 | 1,408 | 176 | 7.04 | 7 | 1.35 |
| Propane | 110 | 110 | 20 | 532 | 2,722 | 136 | 5.44 | 7 | 1.05 |

with these temperatures lowered 2°F per week along with the room temperature. Variation would have been less if the controller on-off set points had been 0.5°F apart versus the 1°F difference in the setting.

Black globe temperature in the pens with the propane brooder were consistently 1-2°F above black globe temperatures in the pens with heat lamps. The temperature settings for the propane controller and the height of the electric heat lamps were chosen with the intent of maintaining consistently comfortable thermal conditions in each pen (based upon operator observations and experience). The goal was to have the pigs select the mats directly under the heat source as the preferred sleeping area, and when sleeping to be in a "pig-and-a-half pile" in terms of sleeping posture. The fact that standard deviations in air and black-globe temperatures within treatments were relatively low suggests that farm management was able to produce similar thermal environments within similar zone-heating treatments.

Black globe temperatures were very similar for both wood and rubber mats (Figure 2). The slightly higher black globe temperature for the wood mats versus the rubber mats may be due to a slightly greater infrared heat absorption (less reflected heat) for the black mats versus the natural colored wood mats.

Daily energy usage, expressed in Btu units, is presented in Figure 3. This figure also contains a plot of the 24-hour average outside air temperature.

The annualized fixed costs of each heating system are presented in Table 2. While there were 15 pigs per pen in the experimental facility, fixed costs are estimated based on 25 pigs per pen, a more typical situation. Brooder fixed costs are estimated for eight brooders, similar to what was used in this experiment, and for 20 brood-

**Table 3. Total estimated operating and ownership costs for the experimental heating systems at various energy rates.**

| | Annualized fixed cost @ i=8% ($/yr/pig) | 250W bulb ($/pen/yr) | Electric use (kWh/pen/d) | Electric rate ($/kWh) | Electric cost ($/pen/yr) | Electric cost ($/pig/yr) | Operating cost ($/pen/yr) | Operating cost ($/pig/yr) | Total cost ($/pig/yr) |
|---|---|---|---|---|---|---|---|---|---|
| Lamps | 0.08 | 1.8 | 6.0 | 0.06 | 15.12 | 1.01 | 16.92 | 1.13 | 1.20 |
| Lamps | 0.08 | 1.8 | 6.0 | 0.07 | 16.63 | 1.11 | 18.43 | 1.23 | 1.31 |
| Lamps | 0.08 | 1.8 | 6.0 | 0.08 | 18.90 | 1.26 | 20.70 | 1.38 | 1.46 |
| Lamps | 0.08 | 1.8 | 6.0 | 0.09 | 22.68 | 1.51 | 24.48 | 1.63 | 1.71 |
| Lamps | 0.08 | 1.8 | 6.0 | 0.12 | 30.24 | 2.02 | 32.04 | 2.14 | 2.21 |
| | | | LP gas use (gal/pen/d) | LP gas rate ($/gal) | LP gas cost ($/pen/yr) | LP gas cost ($/pig/yr) | Operating cost ($/pen/yr) | Operating cost ($/pig/yr) | Total cost ($/pig/yr) |
| Propane | 1.35 | | 0.381 | 0.70 | 11.20 | 0.75 | 11.20 | 0.75 | 2.10 |
| Propane | 1.35 | | 0.381 | 0.77 | 12.32 | 0.82 | 12.32 | 0.82 | 2.17 |
| Propane | 1.35 | | 0.381 | 0.88 | 14.00 | 0.93 | 14.00 | 0.93 | 2.29 |
| Propane | 1.35 | | 0.381 | 1.05 | 16.80 | 1.12 | 16.80 | 1.12 | 2.47 |
| Propane | 1.35 | | 0.381 | 1.40 | 22.40 | 1.49 | 22.40 | 1.49 | 2.85 |
| Propane | 1.05 | | 0.190 | 0.70 | 5.59 | 0.37 | 5.59 | 0.37 | 1.42 |
| Propane | 1.05 | | 0.190 | 0.77 | 6.14 | 0.41 | 6.14 | 0.41 | 1.46 |
| Propane | 1.05 | | 0.190 | 0.88 | 6.98 | 0.47 | 6.98 | 0.47 | 1.51 |
| Propane | 1.05 | | 0.190 | 1.05 | 8.38 | 0.56 | 8.38 | 0.56 | 1.60 |
| Propane | 1.05 | | 0.190 | 1.40 | 11.17 | 0.74 | 11.17 | 0.74 | 1.79 |

ers, a more typical installation. The difference in these scenarios is the larger number of pigs available to spread the expense of the modulating gas valve and regulator.

Total operating and ownership expenses at various energy prices are presented in Table 3. Operating expenses are based on two turns of pigs per year. It is possible that operating expenses for the propane brooders are over estimated in this scenario since the data is based on usage of brooders in January and February. It would be logical to expect a lower rate of propane usage for summer weaning. However, since heat lamps use a fixed rate of energy, their usage for winter versus summer months is probably more similar. For the number of pens used in this experiment, the brooders are not as cost efficient, regardless of energy prices when compared to the electric heat lamps. However, when the installation costs are spread over a larger number of pens and pigs, the difference in costs narrows considerably. This suggests that with energy expenses in the range of $0.08/kWh for electricity and $0.88/gal for propane, total operating and fixed costs for the two heating systems may vary as little as $0.05/pig.

## Conclusions

The lack of differences in pig performance between treatments during both the 21-day post-wean period and overall suggests that any of the combinations of heating system and mat materials is capable of providing for the weaned pigs needs if managed correctly. These results suggest that producers with wean-to-finish facilities can base their selection of zone heating systems on criteria other than pig performance, such as ease of use, installation and operating expense, etc.

[1]Mike Brumm is a professor of animal science and extension swine specialist and Sheryl Colgan is a research technologist at the Northeast Research and Extension Center, Concord, Neb.; Richard Stowell is an assistant professor in the Biological Systems Engineering department. This research was financially supported by a grant from the National Pork Board per the recommendations of the Nebraska Pork Producers Association.

# Rapid Methods to Predict Lean Quality Attributes in Pork

**Chris R. Calkins**
**Tony W. Holthaus**
**Roger C. Johnson**
**Kent M. Eskridge**
**Eric P. Berg** [1]

**Summary and Implications**

*Meat quality has a significant impact on the value of pork. This research was conducted to determine if measures taken within the first 24 hours after harvest could be used to predict final meat quality in the domestic and export market. Measurements of loin pH, electrical impedance, and light reflectance were taken at the last rib 22 hours postmortem on 604 pigs in a commercial meat plant. One loin from each carcass was stored for 21 or 42 days to simulate domestic or export handling and shipping. At the conclusion of the storage time, pork color and loin purge were assessed. Measures taken within a day of slaughter were used to construct prediction equations for ultimate color and purge in domestic and export product. Color (L*, a measure of lightness) was determined using a colorimeter and purge was defined as the percentage of boneless loin weight found as free liquid in the vacuum package after storage. Prediction equations explained only 21% and 12% of the variation in percent purge for domestic and export product, respectively, and 29% and 44%, respectively, of the variation in L*. Electrical impedance and light reflectance were of limited value in predicting pork quality within narrow quality classes when the measurements were made on cold carcasses.*

**Introduction**

Consumers use pork color as a selection criterion when purchasing at retail. Thus, color is of considerable economic value. Similarly, loss of loin weight as liquid within the vacuum package (purge) is of economic consequence to processors and retailers. This is true both in domestic and export markets. Many companies that purchase pork from packing plants impose a minimum color standard and have expectations as to the amount of purge that will occur within the vacuum package. For a packing company involved in the harvest and processing of pork, the ability to sort pork into known quality classes on the basis of ultimate color and purge would be of considerable value.

Many methodologies have been applied to prediction of pork quality. Recently, attention has been directed toward electrical impedance as a possible indicator of pork quality. Unfortunately this technology requires measures be taken on hot, pre-rigor carcasses. A more logical location in the processing plant to make such measures would be after chilling, when the normal flow of product through the facility could be better managed.

In addition, light reflection within the lean (which can be measured from an optical fat probe) has been suggested as an indication of pork color. Thus, the objective of this research was to determine if measures taken within the first 24 hours after harvest could be used to predict final meat quality in the domestic and export market.

**Procedures**

Two commercial dam lines were crossed with two commercial sire lines and the progeny (barrows and gilts) were harvested at a commercial packing plant during two seasons (summer and winter). There were four harvest dates per season with about 80 animals per day. There were 604 pigs used in the study.

Within 30 minutes postmortem, a Fat-O-Meater™ Optical Probe (SFK Technology, Herlev, Denmark) was used to measure fat and muscle depth on each carcass. Measures were taken at the 10/11 rib interface. Carcass weight was also recorded. About 21 hours later, muscle pH (with a probe electrode), electrical impedance (NTE Meat Quality Scanner, model MQS-1, Barcelona, Spain) and light reflectance (Hennessy Grading System probe, model GP4/MPS7, Auckland, New Zealand) measurements were made at the last rib.

The electrical impedance instrument actually generates six distinct data points, representing the real and imaginary components of impedance at three different wavelengths (5.6, 56, and 112 kHz). A preliminary analysis was conducted to determine which, if any, of these variables ought to be included in the final model. This was necessary because of the high degree of interrelationship between the measures. For purge, the imaginary portions of impedance measured at 56 and 112 kHz were of greatest significance. For color, no relationships were found, although these two variables were also used in color prediction equations to maintain consistency in the analyses.

**Table 1. Means and variation for carcass traits of pork carcasses used as a source for domestic pork loins.**

| | Summer harvest | | | Winter harvest | | |
|---|---|---|---|---|---|---|
| | Mean | SD[a] | CV[b] | Mean | SD | CV |
| Hot carcass weight, kg | 197.1 | 19.5 | 9.9 | 187.6 | 17.9 | 9.5 |
| Fat depth, mm | 18.0 | 4.1 | 22.8 | 18.0 | 4.1 | 22.8 |
| Muscle depth, mm | 56.1 | 6.7 | 11.9 | 51.7 | 7.3 | 14.1 |
| Ultimate L* | 50.2 | 2.8 | 5.6 | 46.8 | 4.1 | 8.8 |
| Ultimate purge, % | 3.1 | 1.3 | 41.9 | 4.1 | 1.9 | 46.3 |

[a]SD = standard deviation.
[b]CV = coefficient of variation; SD/mean x 100.

**Table 2. Means and variation for carcass traits of pork carcasses used as a source for export pork loins.**

| | Summer harvest | | | Winter harvest | | |
|---|---|---|---|---|---|---|
| | Mean | SD[a] | CV[b] | Mean | SD | CV |
| Hot carcass weight, kg | 196.6 | 20.7 | 10.5 | 187.2 | 17.5 | 9.3 |
| Fat depth, mm | 17.7 | 4.1 | 23.2 | 17.7 | 3.6 | 20.3 |
| Muscle depth, mm | 55.8 | 6.9 | 12.4 | 52.2 | 6.7 | 12.8 |
| Ultimate L* | 49.0 | 2.5 | 5.1 | 48.0 | 2.6 | 5.4 |
| Ultimate purge, % | 3.1 | 1.4 | 45.2 | 3.6 | 1.4 | 38.9 |

[a]SD = standard deviation.
[b]CV = coefficient of variation; SD/mean x 100.

A boneless loin was obtained from each carcass and vacuum packaged. To mimic handling of product in the domestic market, one half of the loins were stored at 1 C for 21 days. For the other half of the loins, handling for the export market was simulated by storage at 1 C for 42 days. All loins were shipped from Nebraska to Missouri during storage.

At the completion of storage time, muscle color (L*) was measured at the anterior end of the loin with a Color-Tec colorimeter (Clinton, NJ). Purge loss percentage was quantified by weighing the boneless loin in the vacuum bag and then without the bag.

It should be noted that the instruments for light reflectance and impedance were designed for measurement on hot carcasses. The equipment in this study was used on cold carcasses because of plant layout and the opportunity to sort prior to fabrication. All other procedures followed manufacturers' recommendations. Regression equations were constructed to explore the relationship between quality (L* and purge) and the objective measures that were taken. For purposes of this analysis, acceptable quality was defined as an L* value less than 50 and purge loss of less than 5%.

## Results and Discussion

The populations of carcasses used for this study were fairly consistent for carcass weight and muscle depth (Tables 1 and 2). These traits have coefficients of variation on the order of 10%. Carcass fatness was more variable with a coefficient of variation around 25%. Similarly, ultimate color, L*, had a coefficient of variation between 5 and 9%. The amount of purge, while variable on a percentage basis, was generally low, with means of 3-4%. It is generally difficult for prediction technology to perform well on such a consistent population.

To evaluate the effectiveness of the technology, variables were added to the regression equation in a sequential fashion going from the easiest to the most difficult data to collect. Thus, we began with season, adding carcass weight and characteristics that would normally be collected with the Fat-O-Meater (fat and muscle depth). Color and color variation from the Hennessy Grading Probe were added next, followed by muscle pH. Electrical impedance data were the last group to be added to the model. In this way, it was possible to evaluate the additional increase in predictive accuracy provided by each of the technologies and thus to determine which equation would be most cost effective. Some terms were included in the statistical model despite lacking a significant contribution to the equation. This was to maintain clarity and consistency during evaluation and presentation of the methodologies described here. No differences in interpretation occurred when nonsignificant terms were removed from the model.

Results for color of domestic (Table 3) and export (Table 4) loins revealed that none of the equations were particularly effective in predicting ultimate L*. In both populations, there was a significant improvement in prediction when color data from the Hennessy Grading Probe were added to the model. Still, only 22 to 38% of the variation in color was explained. The slight improvement in predictive accuracy provided by pH and electrical impedance do not seem to justify the additional expense of data collection in a plant setting.

To evaluate the effectiveness of the prediction equations in allowing a plant to sort pork carcasses at 24 hours on the basis of predicted color in the domestic or

*(Continued on next page)*

**Table 3. Prediction of ultimate color (L*) in pork loins (n=302) destined for the domestic market.**

| Model[a] | R-square | RMSE[b] | Overall accept, % | Correct accept, % | Incorrect accept, % | Overall reject, % | Correct reject, % | Incorrect reject, % |
|---|---|---|---|---|---|---|---|---|
| S | 0.00 | 3.44 | 0.00 | 0.00 | 0.00 | 100.00 | 16.22 | 83.77 |
| S + Carc | 0.03 | 3.40 | 0.00 | 0.00 | 0.00 | 100.00 | 16.22 | 83.77 |
| S + Carc + HGP | 0.22 | 3.07 | 25.16 | 23.84 | 1.32 | 74.83 | 14.90 | 59.93 |
| S + Carc + HGP + pH | 0.28 | 2.95 | 27.81 | 26.49 | 1.32 | 72.18 | 14.90 | 57.28 |
| S + Carc + HGP + pH + EI | 0.29 | 2.95 | 27.81 | 26.82 | 0.99 | 72.66 | 15.23 | 56.95 |

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as an L* value less than 50.
[b]RMSE = root mean square error.

**Table 4. Prediction of ultimate color (L*) in pork loins (n=302) destined for the export market.**

| Model[a] | R-square | RMSE[b] | Overall accept, % | Correct accept, % | Incorrect accept, % | Overall reject, % | Correct reject, % | Incorrect reject, % |
|---|---|---|---|---|---|---|---|---|
| S | 0.14 | 2.32 | 52.31 | 50.33 | 1.98 | 47.68 | 10.26 | 37.41 |
| S + Carc | 0.17 | 2.29 | 52.31 | 45.69 | 1.98 | 47.68 | 10.26 | 42.05 |
| S + Carc + HGP | 0.38 | 1.99 | 50.00 | 47.68 | 2.31 | 50.00 | 9.93 | 40.06 |
| S + Carc + HGP + pH | 0.43 | 1.91 | 51.98 | 49.66 | 2.31 | 48.01 | 9.93 | 38.07 |
| S + Carc + HGP + pH + EI | 0.44 | 1.90 | 51.98 | 50.66 | 1.32 | 48.01 | 10.92 | 37.08 |

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as an L* value less than 50.
[b]RMSE = root mean square error.

export market, the percentage of loins that would be predicted to be acceptable was determined. The percentages of correct and incorrect decisions were also identified (Tables 3 and 4). To make this calculation, it was presumed that the acceptable risk of an individual loin not meeting the acceptability criterion of L* < 50 was 20% (alpha = 0.2). This level of performance was not well met by any of the equations. For example, in Table 3, the equation containing season, carcass data, and information from the Hennessy Grading Probe correctly predicted that 23.84% of the pork loins for domestic consumption would meet the standard. While only 1.32% of the population was incorrectly accepted, 59.93% of the population was incorrectly rejected. This means that nearly 85% of the loins would have actually met the standard, but the prediction equation would have allowed less than 25% of the population to be accepted. The high level of uncertainty on the quality prediction leads to this conservative result.

One might be tempted to accept a higher proportion of the population based on these data. However, the consequences of a single loin not meeting the color standard are significant. For a meat plant to guarantee every loin will be of acceptable color, the presence of one in five with unacceptable color (the 20% standard set by alpha = 0.2) would be considered a very high failure rate. From this one can conclude that the prediction of ultimate color by the technologies used in this study, and applied the way we applied them, was of limited value.

In a similar way, prediction of ultimate purge percentage was equally unsuccessful (Tables 5 and 6). Here, about 81% of the domestic loins and 87% of the export loins possessed an acceptable level of purge (< 5.0%) yet the most complex equation accepted 18 - 33% of the loins and incorrectly rejected 55-61% of the population. Clearly, prediction of ultimate

**Table 5. Prediction of ultimate purge loss in pork loins (n=302) destined for the domestic market.**

| Model[a] | R-square | RMSE[b] | Overall accept, % | Correct accept, % | Incorrect accept, % | Overall reject, % | Correct reject, % | Incorrect reject, % |
|---|---|---|---|---|---|---|---|---|
| S | 0.08 | 0.016 | 0.00 | 0.00 | 0.00 | 100.00 | 19.53 | 80.46 |
| S + Carc | 0.09 | 0.016 | 2.31 | 2.31 | 0.00 | 97.70 | 19.53 | 78.14 |
| S + Carc + HGP | 0.18 | 0.016 | 15.23 | 12.91 | 2.31 | 84.76 | 17.21 | 67.54 |
| S + Carc + HGP + pH | 0.18 | 0.016 | 20.19 | 19.20 | 0.99 | 79.80 | 18.54 | 61.25 |
| S + Carc + HGP + pH + EI | 0.21 | 0.015 | 20.19 | 18.87 | 1.32 | 79.80 | 17.88 | 61.58 |

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as less than 5% purge loss.
[b]RMSE = root mean square error.

**Table 6. Prediction of ultimate purge loss in pork loins (n=302) destined for the export market.**

| Model[a] | R-square | RMSE[b] | Overall accept, % | Correct accept, % | Incorrect accept, % | Overall reject, % | Correct reject, % | Incorrect reject, % |
|---|---|---|---|---|---|---|---|---|
| S | 0.03 | 0.014 | 52.31 | 46.31 | 6.00 | 47.68 | 6.28 | 41.40 |
| S + Carc | 0.05 | 0.014 | 33.11 | 29.13 | 3.97 | 66.88 | 8.27 | 58.60 |
| S + Carc + HGP | 0.07 | 0.014 | 36.75 | 32.11 | 4.63 | 63.24 | 7.61 | 55.62 |
| S + Carc + HGP + pH | 0.09 | 0.014 | 39.73 | 34.76 | 4.96 | 60.26 | 7.28 | 52.98 |
| S + Carc + HGP + pH + EI | 0.12 | 0.014 | 37.08 | 32.78 | 4.30 | 62.91 | 7.94 | 54.96 |

[a]S=season; Carc = carcass measures of fat depth, muscle depth, and hot carcass weight; HGP = Hennessy Grading Probe measures of color and color variation; pH = muscle pH at 22 hr postmortem; EI = the imaginary component of electrical impedance at 56 and 112 kHz. Acceptable color was defined as less than 5% purge loss.
[b]RMSE = root mean square error.

purge percentage was not accomplished.

There are several reasons for these results. A significant issue may have been the relatively uniform population of pork carcasses that was studied. They were very similar in weight and did not differ much in ultimate color. Purge, while variable when expressed on a percentage basis, was also fairly consistent with a standard deviation of less than 2%. Had we used a more variable population similar to that found in many pork packing plants, it's possible better results would have been obtained in screening out the unacceptable loins.

Secondly, the technology was applied after approximately one day of chilling. The electrical impedance probe was designed for use on hot carcasses. Space constraints in the plant forced us into using the probe on chilled carcasses. Better results may have been obtained from hot carcasses.

Finally, the ultimate color was defined as coming from the crosscut surface of the anterior end of the boneless loin. That's because the shoulder end tends to exhibit the worst color from one end of the loin to the other, possibly due to the additional muscles overlapping the end of the loin. Results presented here relate predictive measures taken from the last rib region of the carcass to color of the anterior end of the boneless pork loin.

## Conclusion

Results indicate that electrical impedance and light reflectance were of limited value in predicting pork quality (color and purge) within narrow quality classes when the measurements were made on cold carcasses, as in this study.

[1]Chris R. Calkins is a professor in the Department of Animal Science, Tony W. Holthaus is a former graduate student, Roger C. Johnson is with Farmland Foods, Kent M. Eskridge is a professor in the Department of Statistics, and Eric P. Berg is assistant professor of Animal Science at the University of Missouri.

# Does Insulin and Leucine Stimulate Muscle Protein Synthesis?

**Brad Creamer**
**Jason Scheffler**
**Steven J. Jones**[1]

**Summary and Implications**

*Improvement of protein synthesis in muscle will greatly enhance the production of lean pork. This improvement can be traced to changes at the cellular level. The object of this study was to identify the effects of insulin and the branched chain amino acid, leucine on the extent and rate that messenger RNA (mRNA) is translated into protein. Porcine satellite cells were isolated from a 30 lb pig and cultured. The cultured cells were treated with varying levels of insulin and leucine. Increasing levels of insulin and leucine caused an increase in ribosomes, the organelles responsible for synthesis, only after leucine was present in the media in adequate concentrations. With increasing levels of insulin there was an increase in the recruitment of ribosomes into polyribosomes for mRNA translation. However, increasing leucine levels had no effect on polyribosome percentage. In conclusion, insulin stimulates translation of mRNA by increasing both ability and rate. However, adequate levels of amino acid must be available for the stimulation to occur. Increased levels of branched chain amino acid do not create a synergistic effect with insulin to increase polyribosomes for protein synthesis.*

**Introduction**

Pork products are a valuable product of American agriculture and consumers demand lean pork products. Therefore, producers must continue to improve the efficiency of lean meat production. Improved efficiency of lean pork production can be directly related to the rate and efficiency of skeletal muscle protein accretion. Understanding the cellular mechanisms regulating protein accretion in skeletal muscle is an important factor for improving the efficiency of lean-meat production.

Skeletal muscle is the single most valuable component in the pig and is the largest contributor to protein accretion within the animal. Postnatal muscle growth in meat animals is highly dependent on protein accretion. Skeletal muscle growth via protein accretion is highly dependent on the rate and efficiency of both transcription of DNA into messenger RNA (mRNA) and its subsequent translation by ribosomal RNA (rRNA) into protein. This study focused on the translation of mRNA into protein. This was accomplished by measuring the total number of ribosomes and their activity in translating mRNA into protein. The activity was determined by measuring the percent of ribosomes in the polyribosome form.

Insulin and branched chain amino acids — for example, leucine — have been shown to have significant roles in stimulation of muscle protein synthesis. The purpose of this study was to determine if insulin or leucine altered the quantity of ribosomes or their rate of recruitment for protein synthesis. Satellite cells were used in this study because they could be grown in cell culture and more closely represent what would be observed in vivo.

**Methods**

Primary satellite cells were collected from the *semimembranosus* and *semitendinosus* muscles of a 6-week-old female pig weighing 30 lb. After the gilt was sacrificed, muscles were removed from both the left and right side of the animal. Muscles were cut into 1-$cm^3$ cubes and satellite cells were liberated from the tissue using an (enzymatic protease) solution. After cells were released from connective tissue, they were separated from the cellular debris by centrifugation. Cells were plated on 75-mm culture flasks Minimum Essential Media-alpha (α-MEM) with 10% FBS and allowed to proliferate. Once they reached 80 percent surface density, they were removed from the plate and frozen (-80° C).

Cells were removed from the freezer, allowed to thaw and plated

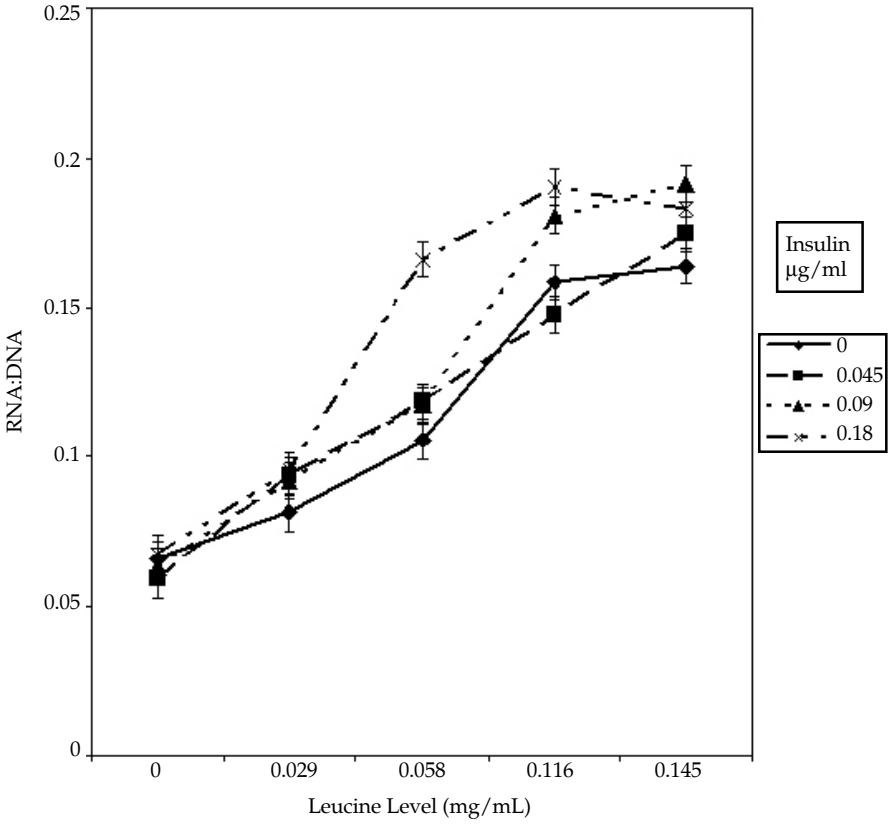



**Figure 1. RNA/DNA in proliferating porcine satellite cells treated with serum-free media containing combined levels of insulin and leucine. (n= 6: SEM = .006)**

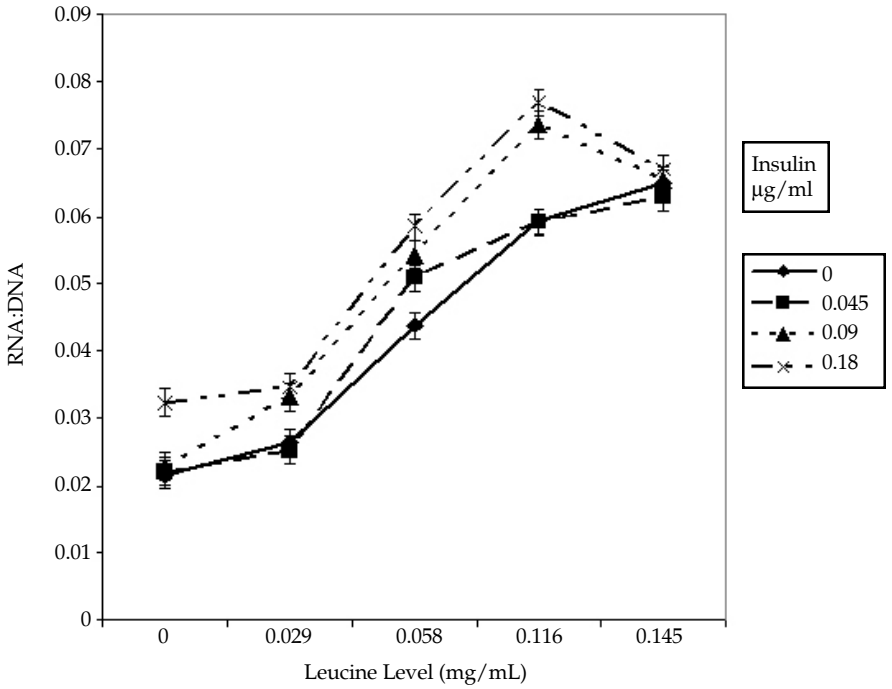



**Figure 2. RNA/DNA in fused porcine satellite cells 48 hours after addition of fusion media, and treated with serum-free media containing combined levels of insulin and leucine. (n= 6: SEM= .002))**

on 6-well plates with 15 ml of culture media and allowed to proliferate until they reached a 80% confluence. Cells at this stage of development were identified as proliferating satellite cells (PSC) and used as one of the cell types. Additionally, replicate plates containing PSC media were replaced with a fusion media consisting of α-MEM plus two percent horse serum to stimulate cell fusion to form myotubes. Previous research indicated that 48 hours after media replacement was the optimum time for treatment of myotubes. This cell type will be referred to as fused satellite cells (FSC).

Both porcine derived PSC and FSC were used in the study using a serum free media. The study was designed using five concentrations of insulin (0 ,0.0025, 0.045, 0.09, and 0.18 µg/ml) with 0.09 µg/ml representing post feeding physiological concentrations and four concentrations of leucine, 0, 0.029, 0.058, 0.116 mg/ml in serum-free media. Each treatment combination was represented with three wells per treatment and the entire experiment was replicated twice.

Cells were removed from the plate using a buffer to prevent RNA degradation and protein, DNA and RNA were determined. The polyribosomes were isolated and separated using an ultracentrifuge then quantified using a gradient fractionator. The percentage of ribosomes in the polyribosome form was determined and used as a measure of the rate of translation. Total protein, DNA and RNA were quantified.

The statistical design was a randomized complete block design with each plate serving as blocking criteria. The experiment was replicated and analysis was done using Statistical Analysis Systems (SAS). Mean separation was accomplished using the least square means statement. All dif-

*(Continued on next page)*

ferences are reported at P < .05 probably.

### Results

Concentrations of RNA and protein were adjusted by cell density by presenting data as a ratio to DNA. Differences in total DNA, and therefore cell densities, were corrected for RNA and protein by presenting the data as a ratio to DNA. No differences were observed in protein and DNA within cell types. In both cell types, RNA concentration increased as the level of leucine increased (Figures 1 and 2). Differences (P<.05) in RNA due to insulin were not observed until the media contained levels of leucine comparable to that normally found in the α-MEM media (0.058 mg/ml). Once the leucine requirement was satisfied, RNA concentrations increased (P < .05) with increasing levels of insulin. In the PSC, the high level of insulin responded with a greater increase at lower leucine levels compared to FSC. The increase in polyribosome percentage with high levels of insulin occurred with leucine concentrations at 0.058 mg/ml in PSC compared to 0.116 mg/ml in FSC. This difference may be due to the leucine requirement being higher for FSC versus PSC or it may be related to the responsiveness of the FSC to insulin. Other studies performed in our lab have shown that the response of FSC to insulin, as well as other hormones, is less than PSC. Another observation in FSC was a decline in RNA levels at the highest insulin and leucine levels. This drop-off in RNA levels may be an aberration of data; it was expected for RNA levels to plateau as they did in PSC.

There was no interaction observed between insulin and

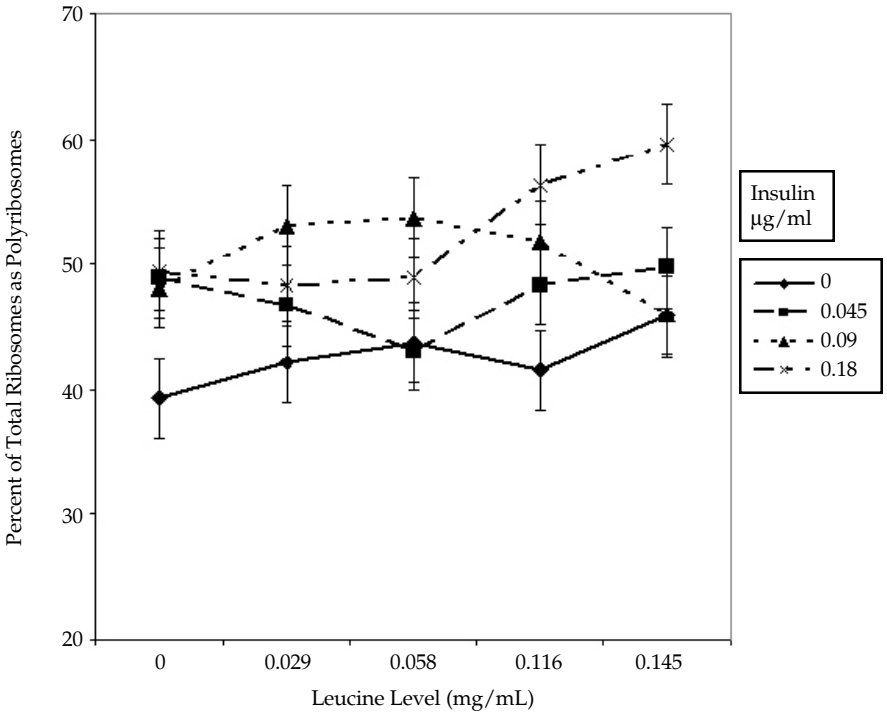



**Figure 3. Polyribosome percentages in proliferating satellite cells exposed to serum-free media containing combined levels of insulin and leucine. (n= 6: SEM = 3.2)**

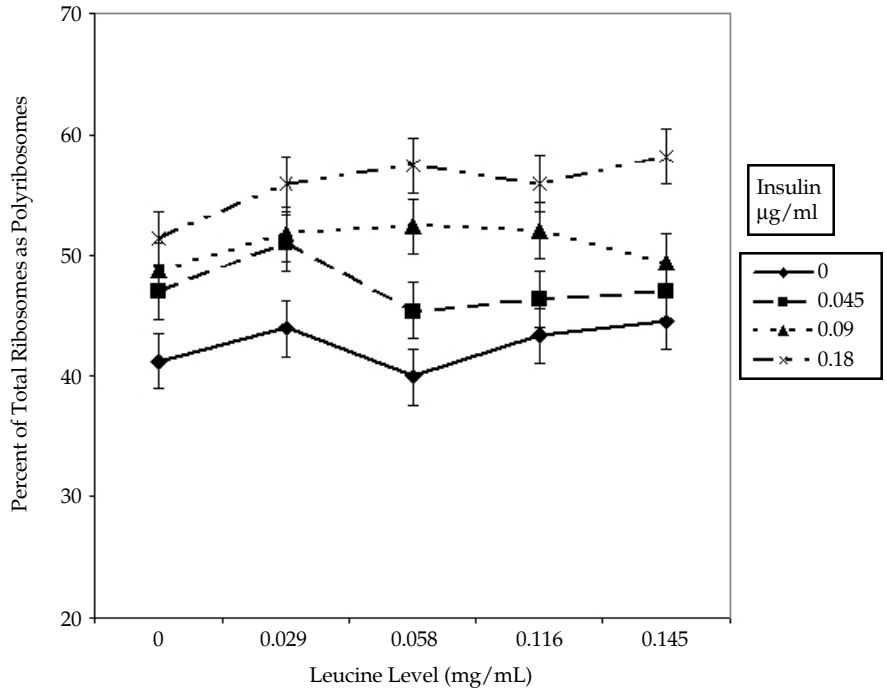



**Figure 4. Polyribosome percentages in porcine satellite cells 48 hours after the addition of fusion media, and exposed to serum-free media containing combined levels of insulin and leucine. (n= 6: SEM= 2.29)**

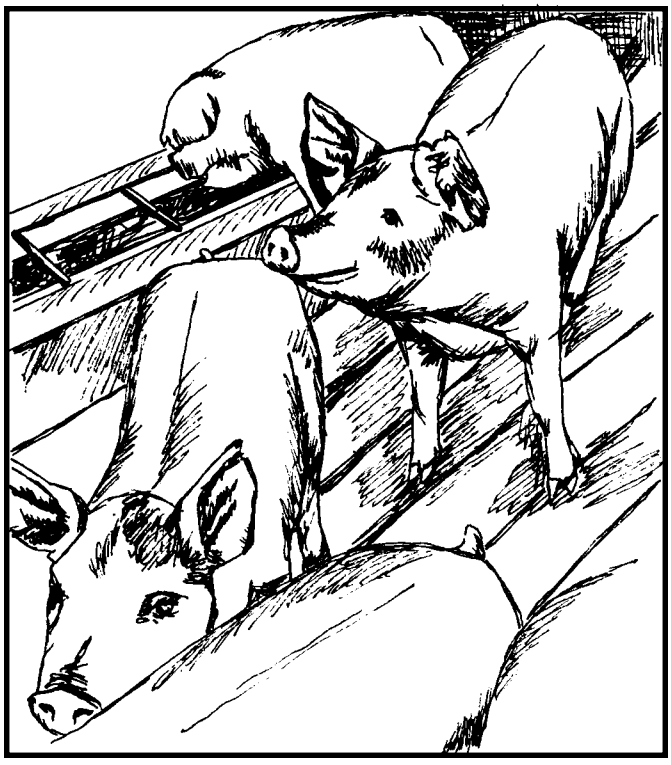
leucine with regard to polyribosome percentage within PSC or FSC (Figure 3 and 4). Regardless of leucine levels, polyribosome percentages were higher with increasing levels of insulin for PSC, with main effect estimates of 42.5, 47.4, 50.6, and 52.5 percent for insulin levels 0, 0.045, 0.09, and 0.18 µg/mL treatments, respectively. Similar results were observed in FSC, with insulin effects estimates, regardless of leucine levels, being 42.6, 47.4, 50.9, and 55.7 percent for insulin levels 0, 0.045, 0.09, and 0.18 µg/mL treatments, respectively. In both PSC and FSC increasing levels of leucine had no effect on ribosome recruitment to polyribosomes.

**Discussion**

Other researchers have observed that both insulin and amino acids have been shown to have significant roles in the stimulation of protein synthesis by increasing the total amount of rRNA; (the machinery responsible for synthesis and the rate of recruitment for protein synthesis in muscle). One group of researchers demonstrated in neonatal pigs that insulin and amino acids increase protein synthesis, but these effects are not additive. Our study demonstrated insulin's powerful effect on protein synthesis by increasing both the number of ribosomes and rate polyribosome formation which functions to synthesize proteins in muscle. Leucine concentrations only impacted the rate of protein synthesis by increasing the amount of rRNA. This response is greater in myoblasts when compared to myotubes. Other studies in our lab have shown fractional protein synthesis rates are higher in the myoblasts compared to myotubes. Only when the amino acids requirements are met can the full anabolic effect of insulin be realized. If essential amino acids are restricted, increased concentrations of insulin will have no anabolic impact on muscle.

The results of this study demonstrate insulin plays a large role in increasing RNA synthesis as well as its activity in the formation of polyribosomes, which are active in both PSC and FSC *in vitro*. This response can be increased if leucine or possibly other branched chain amino acids are supplemented. It was also observed if leucine concentrations decrease below normal media concentrations, the production of RNA, as well as its activity, was significantly decreased. While insulin caused an increase in RNA and its activity, it does not appear to work synergistically with leucine to increase RNA production in either cell type. Leucine only appeared to impact synthesis rates when it was reduced to below baseline levels.

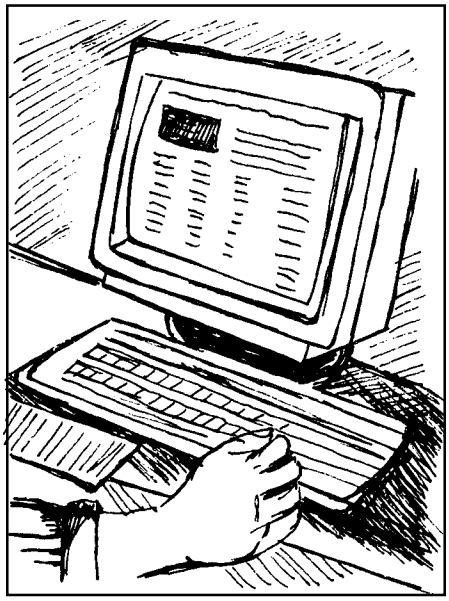
[1]Brad Creamer and Jason Scheffler are graduate students and Steven Jones is a professor in the Animal Science Department at the University of Nebraska-Lincoln.



# Explanation of Statistics Used in This Report

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

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

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

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

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

# College of Agricultural Sciences and Natural Resources

## Who knows more about growing than we do?

## Majors

**Agricultural Sciences Major**
Agribusiness
Agricultural Economics
Agricultural Education
Agricultural Journalism
Agronomy
Animal Science
Biochemistry
Crop Protection
Diversified Agricultural Studies
Food Science and Technology
Grazing Livestock Systems
Horticulture
Mechanized Systems Management
Veterinary and Biomedical Science
Veterinary Technologist

**Natural Resources Majors**
Environmental Soil Science
Environmental Studies
Fisheries and Wildlife
Natural Resources & Environmental Economics
Rangeland Ecosystems
Water Science

**Preprofessional Programs**
Pre-Forestry
Pre-Veterinary Medicine

**Related Majors**
Agricultural Engineering
Biological Systems Engineering

### Transfer Students
- 2 + 2 Transfer agreements with several community colleges and universities
- Transfer scholarships available

### Benefits of CASNR
- 12:1 Teacher to student ratio
- 15:1 Computer to student ratio

### Scholarships
- CASNR awards over $300,000 in scholarships annually
- $400,000 Plummer & Haskell Loan program available for enrolled students

### Educational Opportunities
- World class faculty dedicated to teaching and advising students
- Travel abroad opportunities
- Grants for foreign study programs for credit

### Career Opportunities
- Outstanding opportunities for internships and after-graduation employment
- Career Day held each fall
- East Campus Career Services office is staffed by a CASNR Career Specialist

### Minority Opportunities
- Academic and personal counseling
- MANRRS - Minorities in Agriculture, Natural Resources and Related Sciences
  A national organization for internships, employment and graduate school and scholarship opportunities
  Special minority scholarships available

## Important Contacts


* **Rosalee Swartz**
  **Director of College Relations**

* **Student Ambassadors**
  **(402) 472-2201**

  **OR**

  **(800) 742-8800 ext. 2541**

  **OR**

  **1-866-grow-unl**
  **(1-866-476-9865)**


**casnr.unl.edu**
**OR**
**grow.unl.edu**

**We can help you discover a college filled with possibilities!**

University of Nebraska Lincoln