Sponsors

University of Minnesota
College of Veterinary Medicine

College of Food, Agricultural and Natural Resource Sciences

Extension Service

Swine Center

Thank you to **IDEXX Laboratories** for their financial support to reproduce the conference proceeding book.

Production Leader
Steven Claas

Production Assistant
Steven Claas
Janice Storebo
Sarah Summerbell

Layout and CD-ROM
David Brown
Tina Smith

Logo Design
Ruth Cronje, and Jan Swanson;
based on the original design by Dr. Robert Dunlop

Hanson Lecture

The science of pig production: Past, present, and future

Steve S. Dritz, DVM, PhD, Mike D. Tokach, PhD, Robert D. Goodband, PhD, Joel M. DeRouchey, PhD, Jim L. Nelssen, PhD
Kansas State University Applied Nutrition Team, Manhattan, KS

Our passion is pigs! Within our group we are strong believers in the science of pig production as a vehicle for providing a rewarding professional experience that has an impact on the people and pigs we interact with on a daily basis. We derive great pleasure from the fact that everyday we are involved in the production of food. We all have deep, agricultural-based roots and we are proud to carry on this tradition in food production. It is constantly amazing to sit back and think about the complex interactions it takes in the modern swine industry to provide food. Therefore, our charge today is to share our perspective on the swine industry and our thoughts on how we approach advancing the science of pig production. This has largely been shaped by our experiences and involvement in the swine industry over the last 20 to 25 years. Our perspective is guided by the progress we have made in the past, our experiences solving today's problems in pig production science, and our optimism for the future.

Where have we been? The past

For several of us in the group, one of the foundations to the start of our careers was learning average swine production values from the annual production and economic values published by Swine Graphics, Inc **(Table 1).** These values provided the framework for what were the standards for the science of pig production at the time. Several striking things are noted from these numbers. The first is that market weight has increased dramatically from the 235 lb standard. The second is that the standards for Grow/Finish growth rate are similar to what we would consider for today's standard for wean to finish performance. The standard for feed efficiency has improved dramatically; however, the standard for mortality has remained unchanged. Interestingly, one of the driving forces behind implementation of multi-site pig production systems was the improvement in health, but it has not resulted in decreased mortality.

Our perspective of the past also has been shaped by our interaction with some of the most productive pig farmers in the world. To examine the progress that has been made, we are going to look at examples of the past history of one production system. This was one of the first pig production systems to implement the science of All/In-All/Out by site pig production. While originally implemented as a health control option, one of the biggest benefits was the development of accurate records for the finishing segment of production. Thus, we have a 21 year history of actual production numbers. This is the longest and most accurate set of production records for which we have access.

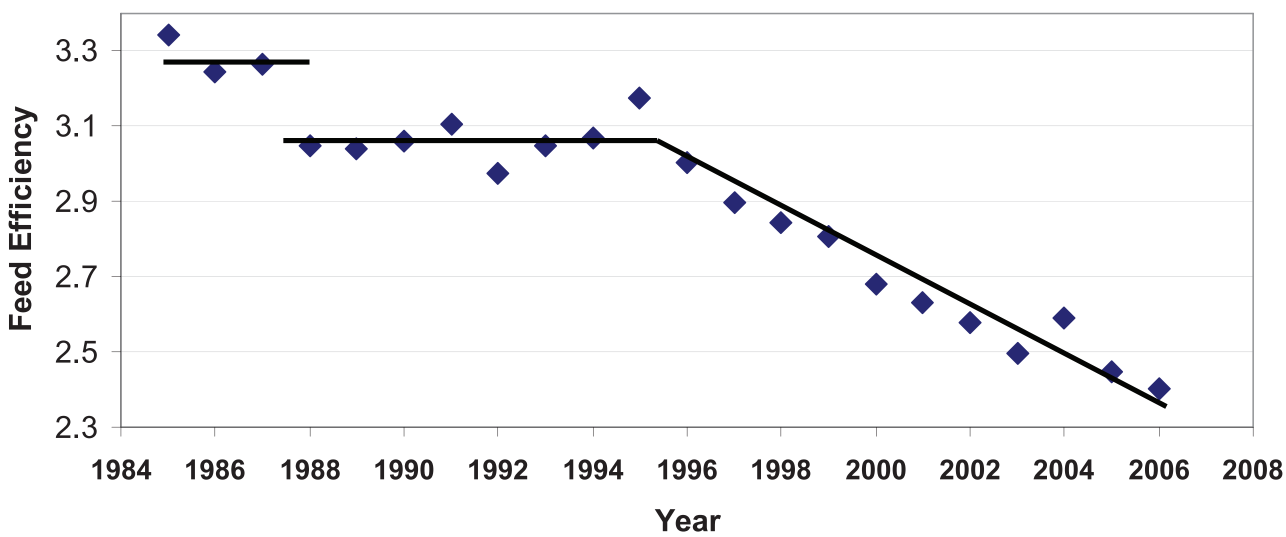
When looking at the history of feed efficiency, there are two major inflection points in the graph **(Figure 1)**. The first is the abrupt change from 1987 to 1988. This change was brought about by a change in genetics. We continue to observe dramatic differences in finishing performance across genetic lines. Although, we acknowledge the need to assess quality attributes and consumer traits, it is still evident that the large amount of feed cost in the grow finish phase dictates that finishing growth performance needs to be the starting base for any kind of genetic decision. The second change is the inflection point beginning in about 1995 with continuous improvement to the present. This is illustrated by no change productivity prior to 1996 and a 2.3% annual rate of change from 1996 to present. The change from 1995 to 2006 represents a 138 lb reduction in feed usage per pig or 4.8 semi-loads of feed every day of the year at the current production system size.

Table 1: Benchmark growing pig performance values.[A]

Stage	Weight Range, lb	Days	ADG, lb	Feed efficiency	Mortality, %	Item
Grow/Finish	50 to 235	127	1.46	3.49	3.0	Actual
		111	1.60	3.30	1.3	Goal
Wean to Finish	12 to 235	186	1.20	3.13	6.6	Actual
		164	1.36	3.10	2.9	Goal

[A]Adapated from Swine Graphics Inc. Grow-Finish Production Values – 1987

Figure 1: Weight adjusted finisher feed efficiency (50 to 250 lb) from 1985 to 2006.



Improvements have been noted in growth rate as well **(Figure 2)**. The first thing to note is that there is more variability over time. This is a reflection of the large impact disease challenge has on growth rate compared to feed efficiency. However, similar trends in productivity are noted with little change until the mid 1990's and an average annual increase of 2.0% from 1998 to present. Assuming the same average market weight, the changes in growth rate from 1998 to present would result in 25.4 fewer days to market and a reduction in contract grower fees of $1.54 million per year at the current weaned pig numbers.

Average market weight was relatively constant until the mid 1990s and then increased to the present 285 pound average **(Figure 3)**. This is over a 50 pound increase from 1985 to present. The market weight increase was largely the result of increased understanding to optimize throughput that maximizes revenue balanced with marginal costs. Interestingly, with the improvements in growth rate, the turn days per group have been relatively constant between 1985 and present. The similar turn days and increased growth rate has resulted in over a 20% increase in the pound produced per pig space **(Table 2)**. While contract grower fees have remained relatively constant over the time period, the contract grower cost per pound has actually decreased because of the increase in productivity.

In regard to mortality plus culls, the productivity changes have been less consistent **(Figure 4)**. Interestingly, when

Figure 2: Finisher ADG from 1985 to 2006.

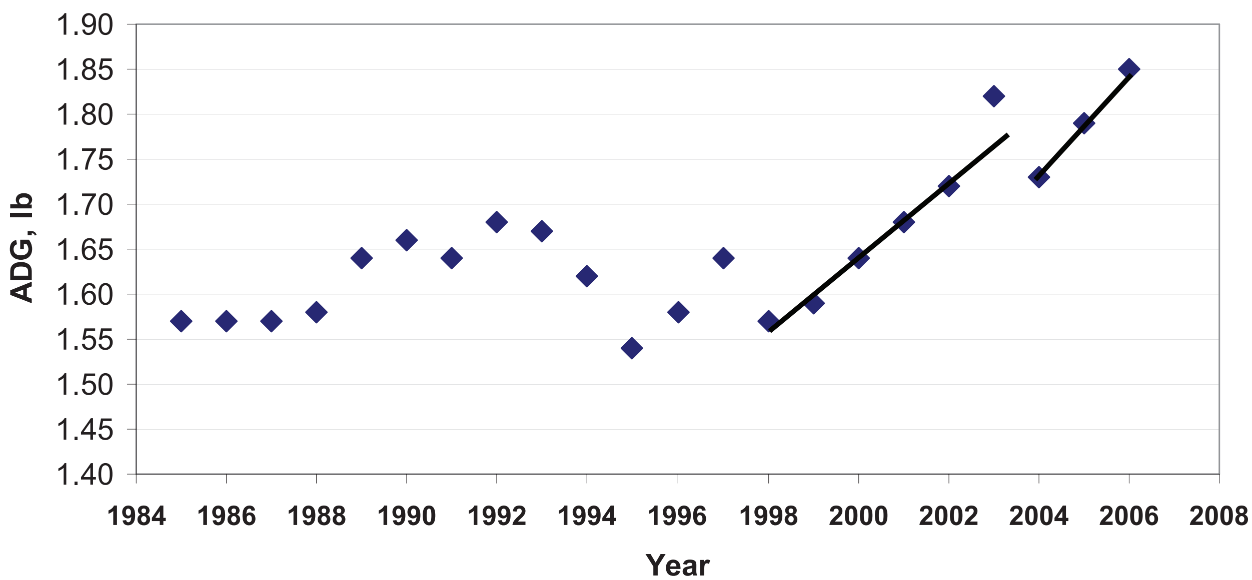
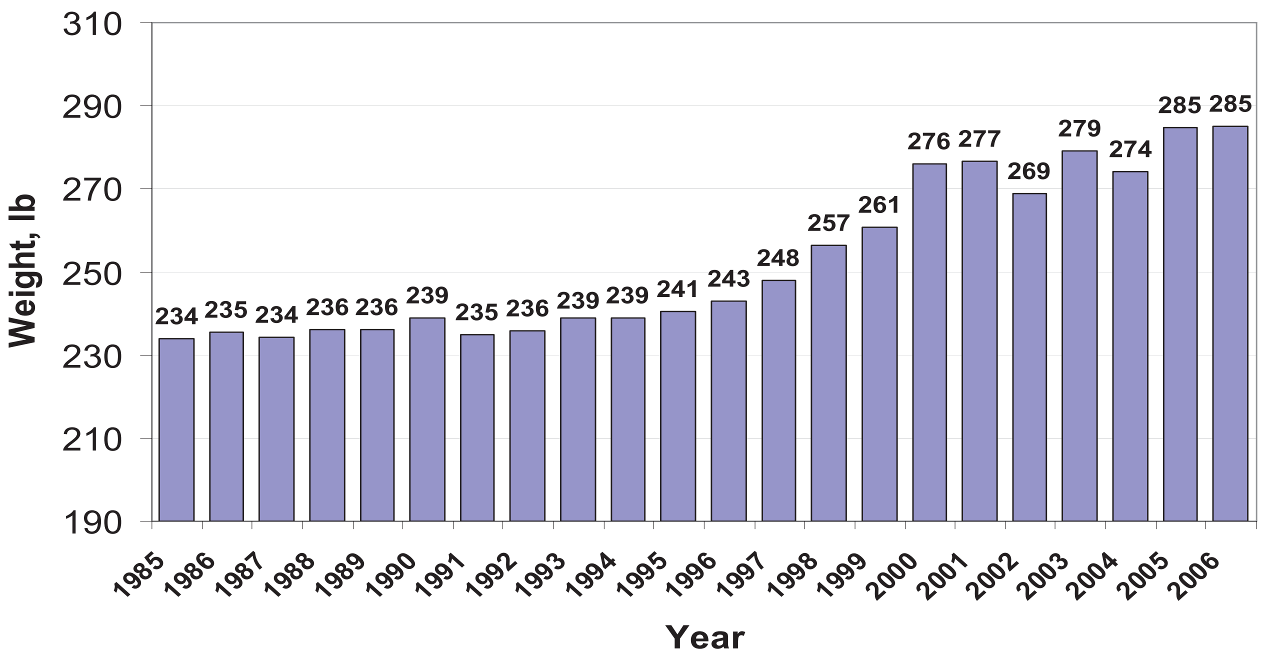


Figure 3: Average market weight (lb) from 1985 to 2006.



looking at the changes per 100 pound of gain there have been increases with specific health challenges but when viewed in this manner mortality plus culling rates have remained relatively constant in the intervening periods **(Figure 5)**. This illustrates the point that interpretation of data can be influenced by the context of how it is analyzed and how it is presented.

These data represent a reflection of how our perspective has been shaped by the past. The feed efficiency and growth rate improvements illustrate the power of sustained incremental changes over a long period of time result in great strides in productivity. We believe the majority of these improvements are due to a concerted effort to implement a commercial scale research program.

Figure 4: Finisher mortality plus culls (%) from 1985 to 2006.

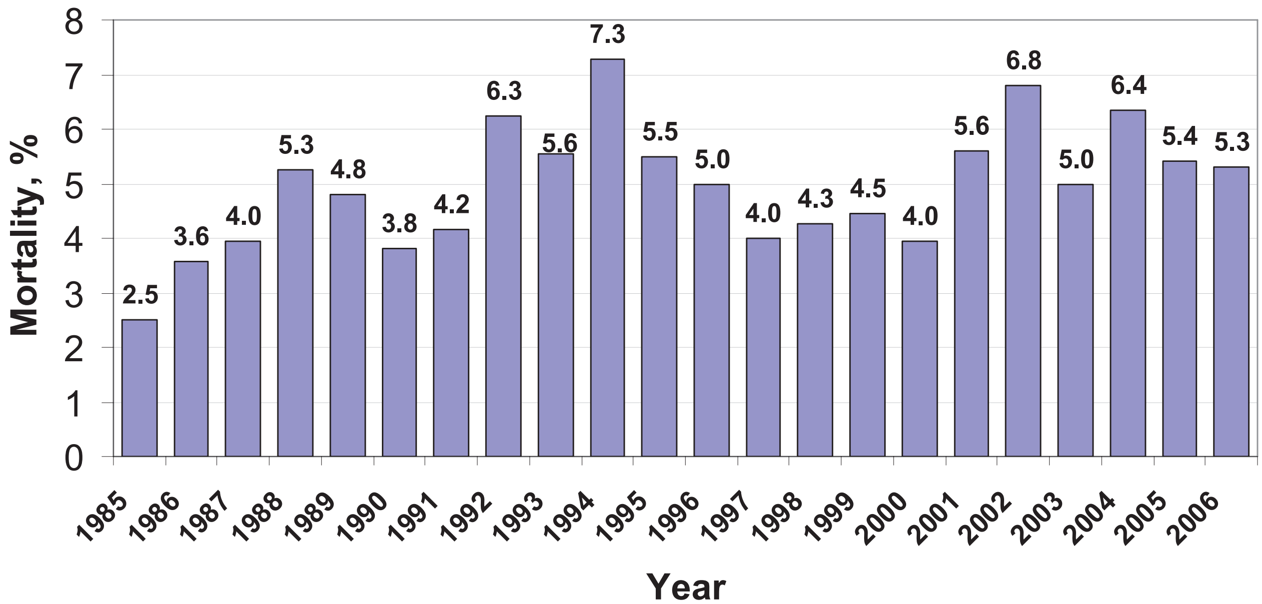
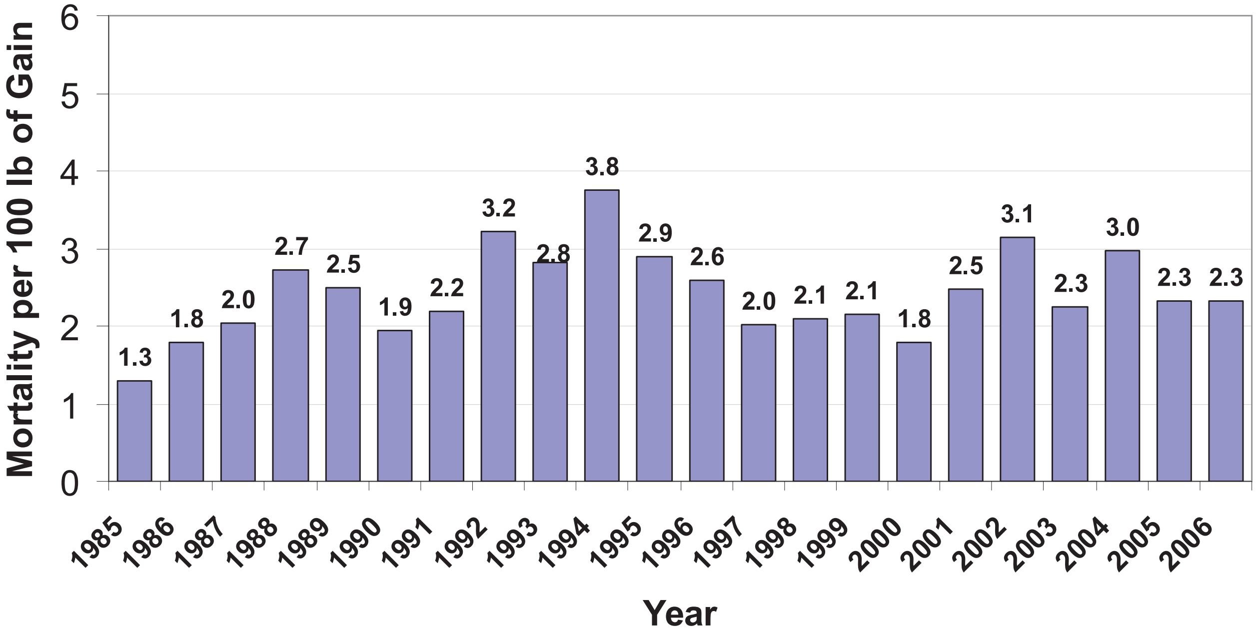


Figure 5: Finisher mortality plus culls (% per 100 lb gain) from 1985 to 2006.



The present: Examples of a science-based approach to solving pig production problems

Weaning age studies: The strength of experimental design

While the results of the weaning age studies by Main, et al. (2004, 2005ab) are striking and have been implemented in many swine production systems, another aspect has been the replication and confirmation of the data across several production systems. We believe a major reason is due to the experimental design of the studies. The first factor to note in the design of the studies is the treatment structure of the two experiments. The first experiment had four treatment weaning ages over a wide range from 12 to 21 days of age. From the initial design of the study, the 12 d of age was chosen to be one increment below the 15 d that was considered to be a practical age that could be practiced on a large scale. The upper limit was chosen by the constraints of the sow farm producing the weaned pigs. Ideally, in retrospect, we would have included another treatment group at 24 d of age. In the second experiment, a factorial design was used to explore the interaction between feeding strategies and weaning age. Factorial designs are very useful in field research. One reason is that if an interaction is observed, it provides insight as to the mechanism of action for the response. The second reason is that factorial designs are useful if you have no reason to suspect there would be an interaction between factors. The lack of interaction leads to an increase in replication without having the added number of experimental units to evaluate the factors individually.

Adequate replication is another key part of the experimental design. Replication is important to understand at several levels. There were four levels of replication in this study at the litter, pig, pen, and group levels. Multiple pen replicates were used per group and four replicate groups to ensure that the response were not confined or biased by normal variations in production over time. Finally, the allotment process was a critical factor in the design. The first step in the process was the randomization of the sows and litters to the weaning age treatments. In this step, the major factor considered was the balancing of sow parity across weaning age treatments because this was considered to be the major known factor that could influence post weaning growth performance. Another critical factor in the allotment process was allocating the weaned pigs to pens. The individual pig weights of over 6,000 pigs were obtained prior to weaning and carefully allotted to pens so that each pen was a representative sample of the weight distribution of the whole population of each group. This

Table 2: Comparison of finishing floor productivity between 1985 and 2006.

	Year	
Item	**1985**	**2006**
Gain, lb	185	235
Days on Feed	119.4	127.0
Turn Days	140.4	141.1
Turns/Year	2.6	2.6
Lb/pig Space	611	737
Change	--	+20%

allowed for extensive economic modeling at the pen level that was representative of the entire population.

Virtually all field experimental designs have some constraint or limitation from the ideal. For example in the weaning age study, the pigs had to be weighed three days before the actual weaning day to allow time for the allotment process. The weaning weight used for the calculation of post weaning growth performance was predicted using a regression equation on a sub sample of pig weights. Ideally, pigs would have been weighed again at weaning to obtain actual weaning weights. However, using an indirect measure did not decrease the accuracy of the data enough to justify the extra resources. One of the toughest parts of experimental design is to judge if the resource constraints lead to too many compromises that the outcome of the study will be questioned. Therefore, some guidelines that result in strengthening experimental design include a clear definition of the question to be answered prior to development of the design, proper randomization and allocation of treatments, and adequate replication.

Gestation feeding tools: An example of bringing science to the feeding of gestating sows

The objectives of gestation feeding programs are as follows: Feed the sow at the lowest cost per day while building body reserves in gilts, replenishing body tissue stores lost in lactation, or keeping the sow from depositing excess body fat that will compromise subsequent lactation performance and longevity. The science on gestation feeding is pretty clear as well. The two major factors that influence gestation feed intake requirements are body weight of the sow which dictates maintenance requirements and the amount of body stores to replenish. However, over many years we have been frustrated by the lack of science in the implementation of gestation feeding programs at the farm level. Our experience has been that the five point body conditioning system is just too subjective for use at the farm level. We have observed large swings in changes in the average body condition of a sow herd with the day to day barn staff unaware of the changes. Therefore, over the last several years our group has had a focus of developing tools to bring more objectivity to feeding gestating sows.

The first challenge is obtaining sow weights at weaning in modern gestation barns. Due to the importance of knowing sow weight; we tried quite unsuccessfully to get production staff at several farms to weigh sows on a regular basis. After this, we focused on developing methods to obtain body weight by indirect methods. Our initial search for an indirect measure of body weight included the use of a heart girth measurement. Heart girth has been a standard indirect measure of weight across several different species. A regression equation highly predictive of body weight was easily obtained by weighing several hundred sows across a variety of farms, genetic types and parities. While we could get more farms convinced to use the heart girth than using scales, the method was not very popular with farm staff. This was mainly due to risk of injury to the staff when obtaining the measurement. Thus, a variety of alternative indirect measures were tested and the flank to flank method developed (Iwasawa, et al., 2004). The flank measurement is taken immediately in front of the hind legs by using a flexible tape measure. This measurement is defined as the measurement from the bottom of the flank on one side of the pig over the top of the highest point of the hip to the bottom of the flank on the other side of the pig. The major reason for not measuring the circumference is to exclude the mammary gland development which leads to highly variable measurements. Subsequently, the regression equation has been tested in developing gilts and boars (Salubo, et al., 2007). We have found the same regression equation works well across a variety of boar weights, sow weights, and developing gilt weights down to about 110 lb (55 kg). The equation for calculating body weight from a flank measurement is BW0.333 in kg = 0.0511 × Flank-to-flank, cm + 0.5687. Another adaptation was the development of color coded weight tapes to classify sow weight into five feeding categories. This tape has five different colors that correspond to a feeding chart to further simplify things for the end user in the barn but still retain the power for more precise gestation feeding.

Subsequently, the challenge was developing a more objective measure of body tissue stores. We have chosen to use back fat depth measured by ultrasound either with a real time ultrasound machine. We acknowledge the scientific arguments that this may not be the perfect measurement due to the fact that back fat reductions may not be predictive of muscle tissue loss or the appropriate measure for all genotypes. However, the ultrasound machine is a tool available on many farms which can be easily harnessed to give us a more descriptive measure of nutrient requirements to replenish or maintain body weight loss.

Based on the weight and back fat category, we have developed a grid to provide a desired feeding level (KSU, 2007). This grid can then be customized using a spreadsheet to adjust for the total born litter size, environmental temperature, and dietary energy density. Another feature of this spreadsheet is an ability to translate the grid into actual feed box settings. Thus if the setting is not the same as the weight delivered, staff at the farm level do not need to make the conversions. It is important to periodically update these settings if the bulk density of the diet changes from the addition of different ingredients or change in the test weight of grain. The latest challenge we have been addressing is the variability in amount of feed delivered at various feed box setting due to the positioning of the drop and the type of drop (Schneider et al, 2007). Based on these studies we have found that feed drop style definitely influences the accuracy of the amount of feed dropped at various settings. Also, we have found that some designs are more variable due to positioning than others. This research illustrates that there are many unique opportunities to facilitate new thinking in the science of pig production.

Can you achieve excellent reproductive and weaning performance with other gestation feeding programs? The answer is clearly yes. Has this method simplified gestation feeding on some farms and provided a more scientific method of feeding? The answer again is clearly a yes. The important thing to acknowledge is the process we took to develop the program lead to the development of a better way of doing things on several farms. We and others will undoubtedly continue to alter and refine the procedures.

PCV2 vaccine field studies

Act 1: The power of field generated data

Act 2: A model for testing vaccine efficacy

Our results evaluating the commercial PCV2 vaccines in field settings are certainly not unique. We believe our approach to evaluating the commercially available PCV2 vaccines in a field setting has been done in a rigorous manner that illustrates the utility of doing sound field research. We have shown a decrease in mortality for vaccinated pigs across a number of trials. However, a more critical aspect was the finding that vaccinated pig growth rate was increased by 10% resulting in almost 20 lb heavier pigs marketed at a similar age as unvaccinated pigs **(Figure 6)**. The increased growth rate resulted in a significant decrease in the number of pigs that failed to meet the minimum market weight goal in the vaccinated group. Also, it should be noted that growth rate of the entire population of vaccinated pigs was increased. Thus, the effects of vaccination were evident throughout the entire population. Subsequently, we have completed or are in the process of completing four other field studies and each study has indicated a significant improvement in growth rate for PCV2 vaccinated pigs. In two of the studies where we have had the ability to measure feed intake, PCV2 vaccinated pigs had better feed efficiency compared to unvaccinated pigs. In these two studies, the economic loss for unvaccinated pigs was estimated to be $3.94 and $8.58 per pig. All of these studies have used a model of housing the vaccinated pigs within the same pen or building in order to measure the direct effects of vaccination. We believe they are a conservative estimate of vaccine efficacy and believe that there may be considerable herd immunity benefits to vaccination as well. While these studies demonstrate the efficacy of the vaccine, more importantly they demonstrate that the economic impact of PCV2 infection on morbidity may be larger than the mortality effects.

A critical aspect of these studies has been the careful allocation to treatment groups to harness the most statistical power from the studies. An example includes allocation within litter to account for litter to litter variability. Probably, the most critical aspect has been just doing all the hard work of weighing the pigs and having the field research experience from our field nutrition research program. Through our nutrition program, we have a wide network of on-farm sites and people that are appropriately trained in data collection methods. These same principles of sound field research also transfer to other areas of pig production.

System specific data analysis: Using data analysis as an educational tool

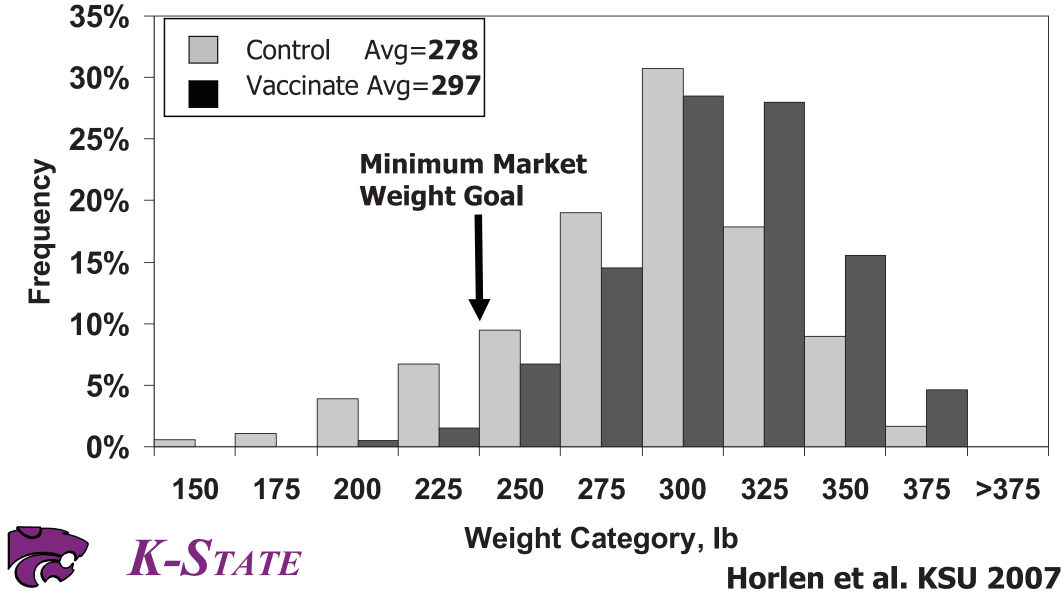
The power of data analysis on the advancement of the science of pig production is provided by an example of retrospective data base analysis. We acknowledge the weakness and pitfalls of retrospective data analysis. However, many times this is the only available data to aid the decision making process within a specific production system and can be a powerful educational tool. We used a data base containing a total of 124 finisher groups across 31 different finisher sites with about 354,000 pigs closed out between 6/21/2005 and 4/12/2007. The objective of the analysis was

Table 3: Feeding levels (lb/day) for gestating sows based on backfat and weight category at breeding[A]

Flank to Flank, inches	Estimated weight, lb	Backfat at breeding, mm: 9 to 11	12 to 14	15 to 17	>18
< 35.5	250 to 325	5.0	4.4	3.9	3.4
35.6 to 38.0	325 to 400	5.5	5.0	4.4	3.9
38.1 to 41.0	400 to 475	5.9	5.4	4.9	4.3
41.1 to 44.0	475 to 550	6.4	5.9	5.4	4.8
> 44.0	550 to 650	6.9	6.4	5.8	5.3

[A]Based on a diet containing 1,500 kcal ME/lb (corn-soybean meal). Feeding level should be increased by 2 lb/d on day 101 of gestation.

Figure 6: Distribution of pig weight at market for PCV2 vaccinated (light bars) versus non-vaccinated control (dark bars) pigs.



to explore the risk factors for Porcine Reproductive Respiratory Syndrome Virus (PRRSv) contamination of sites and quantify the value of biosecurity practices. The data was derived in a production system where the sow farms were negative for PRRSv and nurseries were known to remain free of contamination. Categorization of finishing groups was done by ELISA screening of blood from a sub sample of pigs in each finishing group. Prevalence of PRRSv negative groups was 46%. Growth rate, feed efficiency, mortality, and percentage marketed were all better in the PRRSv negative groups. We estimated that pigs in PRRSv negative groups were $4.10 per pig more profitable than those from positive groups. This is in close agreement with previously published estimates (Neumann, et al., 2005). Further analysis of the data was performed by auditing the number of other pig spaces within 1.5 miles of each of the sites. Sites were categorized as being in less dense areas (< 5,000 pig spaces) or more dense areas (> 5,000 pig spaces). The range in densities for the 1.5 mile radius was from 0 to 15,000 spaces. After analyzing the density data several different ways, we failed to detect any influence of pig density on PRRSv prevalence, growth performance, or mortality rates. Groups also were categorized as having failing or passing biosecurity practices. These practices were mainly comprised as adherence to sanitation, entrance, and load out protocols. Those with a passing score were found to have a lower PRRSv prevalence, higher growth rate and better feed efficiency. The economic value of those groups with a passing biosecurity category was estimated as $5.03 more than those with failing biosecurity practices.

This analysis has been a useful educational tool for production managers and growers as to the cost of disease. The further analysis has eliminated the mentality of some of the growers in high density areas that "I can not change the location of my barn so it is not my responsibility." Finally, this analysis has been a powerful tool for focusing the resources and efforts of the service people to focus on practices that make an impact.

The future: Where are we going?

Certainly, the future has already arrived for some areas of the science of pig production. Clearly, the short term challenge is dealing with the new realities of high feed costs. Long term we are going to have to readjust to feeding low energy diets that will lead to slower growth rates and poorer feed efficiency. Additionally, the cost of milk product ingredient sources will lead to a reevaluation of nursery feeding strategies.

We anticipate continued development of sophisticated mathematical models with simplified user interfaces. These are developed so the end user needs to know little as to how the models are put together but can be easily used to aid decision making processes. A good example is the KSU feed budget spreadsheet. This has been developed to use mathematical modeling to divide the phases and calculate the amount of feed needed for each. However, the user only needs to plug in the weight and feed efficiency values to obtain the output for the feed budget.

Connectivity will continue to advance the science of pig production. Expert opinions can be easily and efficiently sought out over the internet. Furthermore, expectations of rapid turn around time have increased with electronic communication. Electronic storage of data has lead to much wider access to information. Easy access to information has placed a premium on experts who can distill the information in an evidence-based, scientific manner.

Connectivity also can have some downsides leading to over stimulation. Many times when you open up your email and there are 70 to 80 messages that need to be addressed it is easy to become distracted with the urgent but unimportant productivity sapping messages. Cell phone connectivity also can have a negative down side. Some times due to the dependency on cell connectivity front line workers are afraid to make a decision on their own. They lose the critical thinking skills needed to problem solve on their own.

Another trend we envision continuing in the future is the continued privatization of information generation among pig production companies. Several production systems across the US have implemented research barns and internal research programs. These systems will demand higher skilled technical advisors that will help them make decisions and efficiently conduct research in this environment. A challenge for these research programs are understanding of the economics of knowledge with its high up front cost and low cost or no cost marginal cost of implementation once the information is obtained. For example, all the cost of a software program is incurred in the first copy. Subsequent copies have a marginal cost of the media that the program is transferred from one person to another. Similar, economics are noted in drug or vaccine production, the accumulated cost for the first dose sold carries all the cost of development. Subsequent doses are confined to the material, manufacturing, and marketing costs. These costs will typically be a fraction of the subsequent initial research cost. Therefore, there is a trend as resources are allocated to these research programs, individual production systems will maintain proprietary information internally. Traditionally, in the land grant university system, this up front cost has been born by publicly funded research with the information becoming public in a formal scientific process through peer-reviewed publications and dissemination of information through extension. The challenge will be how to capitalize on internally generated data but maintain the knowledge exchange with collogues in the wider pig science community.

Thoughts for the future based on the past

We believe in closing that some of the advice presented by Al Leman 20 years ago at this conference is as relevant to the science of pig production as it was then.

- "Would I hire myself?"
- Use producer support groups and ranking farms
- Develop training programs for hired managers
- Analyze existing information
- Become a systems analyst
- Seek out the best producers as clientele
- Concentrate on reducing costs
- Become an advocate of animal welfare
- Broaden disease control options
- Develop the courage to say "the best action in this case is to take no action"

References

Iwasawa, T., M.G Young, T.P. Keegan, M.D. Tokach, S.S. Dritz. R.D. Goodband, J.M. Derouchey, and J.L. Nelssen. 2004. Comparison of heart girth or flank-to-flank measurements for predicting sow weight. Kansas Swine Industry Day Report of Progress 940.

KSU. Gestation feeding tools. Available at: http://www.asi.k-state.edu/DesktopDefault.aspx?tabindex=1009&tabid=890

Leman, A. D. 1988. Diagnosis and treatment of food animal educational diseases. *JAVMA*. 193:1066-1068.

Main, R. G., S. S. Dritz, M. D. Tokach, R. D. Goodband, and J. L. Nelssen. 2005a. Effects of weaning age on growing pig costs and revenue in a multi-site production system. *J. Swine Health Prod*. 13:189-197.

Main, R. G., S. S. Dritz, M. D. Tokach, R. D. Goodband, K. C. Dhuyvetter and J. L. Nelssen. 2005b. A partial-budgeting tool to describe the effect of lactation space and lactation-space management on net revenue in a multi-site production system. *J. Swine Health Prod*. 13:322-332.

Main, R. G., S. S. Dritz, M. D. Tokach, R. D. Goodband, and J. L. Nelssen. 2004. Increasing weaning age improves pig performance in a multi-site production system. *J. Anim. Sci*. 82:1499-1507.

Neumann, E. J., J. B. Kliebenstein, C. D. Johnson, J. W. Mabry, E. J. Bush, A. H. Seitzinger, A. L. Green, and J. J. Zimmerman. 2005. Assessment of the economic impact of porcine reproductive and respiratory syndrome on swine production in the United States. *JAVMA* 227: 385-392.

Schneider, J.D., M.D. Tokach, S.S. Dritz, R.D. Goodband, J.L. Nelssen, and J.M. DeRouchey. 2007. Determining the accuracy of gestation feed drops. *J. Anim. Sci*. 85 (Suppl. 2): (Abstr.).

Sulabo, R.C., J. Quackenbush, R.D. Goodband, M.D. Tokach, S.S. Dritz, J.M. DeRouchey, and J.L. Nelssen. 2007. Validation of flank-to-flank measurements for predicting boar weight. *J. Anim. Sci*. 85 (Suppl. 2): (Abstr.).