

Proceedings

of the



6th LONDON SWINE CONFERENCE

Thinking Globally, Acting Locally

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of the
LONDON SWINE CONFERENCE

Thinking Globally, Acting Locally

Edited by
J.M. Murphy and T.M. Kane

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Proceedings of the London Swine Conference – Thinking Globally, Acting Locally

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CHAIR'S MESSAGE

Welcome to the 6th London Swine Conference – **“Thinking Globally, Acting Locally”**.

Thinking about and gaining a better understanding of the global pork industry is a key element for the Ontario and Canadian pork industries. The 2005 preliminary trade and production data for Canada shows the importance and dependence on the global market. With over 50% of the Canadian pork production exported to more than 100 countries and 27% of the live pigs produced in Canada exported (mainly to the United States), thinking globally while acting locally is a good fit. Canadian pork is recognized for its quality, uniformity, value, and wholesomeness. Canadian breeding stock and market hogs continue to meet the demands of international customers through the use of superior genetics, health, and production technology. The conference challenges the pork production industry to be at the leading edge of technology and information to create a globally competitive industry.

In response to the feedback from the 2005 participants, this year's conference features more breakout sessions on both days. The plenary sessions provide global perspectives to challenge our thinking on the forces that impact swine production, how research contributes to progress, the handling of disease and the challenges and opportunities from around the world. Breakout sessions allow us to discuss the application of technology at the local level. Sessions deal with nutrition, marketing, gestation housing, weaner room management, meat quality, employees, reproductive innovations, liquid feeding, energy conservation, and managing disease. Over the two day conference, participants will have the opportunity to exchange and discuss ideas with internationally renowned speakers and innovative industry leaders. The presentations, panel discussions, breakout sessions, and networking provide everyone the opportunity to learn.

It is through the hard work and dedicated effort of volunteers, the support of industry partners, and industry wide participation, that the London Swine Conference successfully delivers its objectives. A special thanks to our generous sponsors, who through their financial commitment, support this initiative. Thank you to Ontario Pork, the University of Guelph, and the Ontario Ministry of Agriculture, Food and Rural Affairs for providing the initial foundation for this conference to become what it is today.

The commitment, cooperation, and professional presentations of the speakers are greatly appreciated. To our conference participants, thank you for attending. Your participation and implementation of the technology makes this conference a success.

Enjoy the Conference!

John Bancroft
Chair, Steering Committee
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THE GLOBAL PICTURE – THE FORCES THAT IMPACT ON SWINE PRODUCTION

**Knud Buhl
Danske Slagterier
Rue du Luxembourg 47-51, Bte 2
B - 1050 Bruxelles, Belgium
E-mail: KB@agridan.be**

This presentation will take a look at the forces that have an impact on swine production with special focus on how the World Trade Organization (WTO) system and the present round of WTO negotiations (the Doha round) is expected to influence the general framework for international trade. As the worlds biggest exporter of pig meat the presentation will also look at the consequences for the Danish pig meat sector.

WORLD PIG MEAT MARKET

Before going into the discussion about the consequences of the present WTO negotiations there will be an overview of the world pig meat market and the emerging trends for the world trade in pig meat. The development on the world pig meat market shows that the European Union (EU) pig meat production will remain stable but EU's share of global meat production will decrease in the future compared to other players on the world market. Furthermore the increased global competition against EU meat production in general will be intensified. Another important trend for the pig meat market is that raw materials will be sourced globally but processed locally.

WTO – CONSEQUENCES OF THE DOHA ROUND

The WTO is setting the rules for international trade and for the moment the WTO members are negotiating a new framework for international trade under the so-called Doha round, which began in 2001 in Doha, Qatar. Because the negotiations have not been finalized yet it is difficult to give a clear overview of the consequences for international trade and production. However the negotiations are focusing on 3 pillars, market access, domestic support and export competition.

From the Hong Kong meeting in December 2005 it seems that the main results on agriculture will be a reduction of import duties, reduction of domestic support and export subsidies. Assuming this will be the result and that the Doha round will be concluded in a well-balanced way the presentation will highlight the consequences from this possible outcome.

A reduction of duties is a double-edged sword. On one side, we will benefit from improved market access to our export markets. On the other, the European producers will be exposed to more competition, due to the reduction of import duties. Secondly the consequences of a

reduction of domestic support will be highlighted, mainly focusing on the consequence for the competitive position. Lastly the expected consequences of a reduction of export subsidies will be discussed as to whether it will influence export performance of the main exporters of pig meat.

The presentation will also highlight the dilemma that the Doha round will inevitably result in further reductions of traditional trade barriers. But at the same time that conventional measures to restrict agricultural imports are reduced new barriers to agricultural trade seem to be rising – barriers related to the Sanitary and Phytosanitary (SPS) area. Most of the potential future trade problems will be in this area and ironically the present Doha round does not involve the SPS area.

One of the main conclusions will be that we are not just moving towards more open markets, we are also moving towards less transparent and more complex framework for trade.

MAKING PROGRESS THROUGH RESEARCH

Kees de Lange
Department of Animal and Poultry Science
University of Guelph
Guelph, Ontario N1G 2W1
E-mail: cdelange@uoguelph.ca

ABSTRACT

Improvements in pork production efficiencies and pork meat quality, reductions in environmental impacts of pork production, and improvements in well-being of pigs are the results of new knowledge and the effective application of knowledge in commercial pork production. The return on investment in pork research in Canada is very favourable with an estimated cost-benefit ratio of 22.4 to 1. At the University of Guelph a research program is in place that addresses research goals and objectives that have been established based on industry-wide consultations. Two key supporters of this research program are Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA) and Ontario Pork. This program is the largest pork research program in Canada and is conducted in a wide range of public research facilities and on commercial farms. Increasingly research is conducted in collaboration with partner institutions, such as Agriculture and Agri-Food Canada, commercial companies and, indeed, institutions from around the world. Given the increasing complexity of research activities and high costs of conducting state-of-the-art research, effective collaboration with partner institutions is critical for the development of new and useful technologies, or to support new policies for the industry. A complete overview of research activities and research findings at the University of Guelph can be accessed via the internet (www.uoguelph.ca/research/omafra/animals/pork.shtml). The University of Guelph no longer has a mandate for traditional extension activities. Moreover, greater demands from the society at large and reductions in available resources have forced OMAFRA to focus more on policy development and alter its approach to extension activities. As a result, the University of Guelph and OMAFRA rely increasingly on industry partners, such as veterinarians and feed industry personnel, to facilitate the application of new knowledge in commercial pork production. Continued public support will become increasingly important to maintain a solid research infra-structure in Ontario, to train people that will contribute to the Ontario pork industry, and to respond to new challenges and opportunities that may arise in the future. Feedback to the research at the University of Guelph is welcomed.

INTRODUCTION

For the Ontario pork industry to remain internationally competitive, and sustainable, continued improvements in production efficiencies, meat quality, reductions in environmental impacts, and improvements in well-being of pigs are essential. This, in turn, requires effective and rapid application of new knowledge in commercial pork production. Moreover, solid information and new technologies are required to develop or refine policies and regulations,

such as those related to nutrient management, animal welfare, food safety and quality assurance, and management of disease outbreaks. Finally, conducting research provides an important opportunity for training people that can contribute to future success of the Ontario pork industry.

In this paper, a brief overview of public research activities in Ontario is given, some achievements are highlighted, and future perspectives are provided.

PUBLIC RESEARCH ACTIVITIES AND FACILITIES IN ONTARIO

In Ontario, the University of Guelph is the main centre for publicly funded pork production research, in particular since the regional Agricultural Colleges (e.g. Ridgetown College) have become part of the University of Guelph. During the last several years, the total annual budget for pork research has varied between \$6 and \$7 million, making the program at the University of Guelph the largest pork research program in Canada. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) provides very substantial financial support for this research, about 45% of total funds, under the unique OMAFRA and University of Guelph research partnership program. This agreement is re-negotiated every four years. Apart from OMAFRA, Ontario Pork (about 15% of total) and the Natural Sciences and Engineering Research Council of Canada (NSERC) are the largest financial supporters of pork research, followed by a large number of public funding agencies and private companies.

The University of Guelph/OMAFRA Pork Research Program currently supports 45 research projects that involve 38 different lead researchers that are supported by an even larger number of graduate students, research technicians, post-doctoral fellows and research associates. Information on each of these projects is available via the internet (www.uoguelph.ca/research/omafra/animals/pork.shtml). These research projects are organized by goals and objectives, which are established based on industry wide consultation and under the direction of the Agricultural Research Institute of Ontario (ARIO). Under this program, researchers have the freedom to explore innovative ideas that are consistent with the program's goals and objectives. A committee of experts, representing the scientific community, OMAFRA, and the commercial industry, reviews new research proposals and research progress annually. In addition, a formal and external review of the entire pork research program is conducted every four years. A listing of projects that are currently registered under this University of Guelph and OMAFRA partnership program is provided in the appendix to this paper. According to the current research plan, close to 20% of funds are dedicated to environmental research, 30% to pork quality and safety research, 40% towards improvement in production efficiency and 10% to research on animal behaviour and well-being. These are the four key aspects of a sustainable pork production industry in Ontario.

Physical research facilities include a number and diverse types of animal holding facilities that are complemented by a range of laboratory facilities (Table 1). In addition, individual researchers control their own nutrition, physiology, microbiology, or molecular laboratories to support their research activities. The most recent expansion of research capabilities have been in the area of molecular biology and food safety, which reflects the use of the newest

techniques in animal biology research and changes in public concerns about food safety. These facilities provide researchers with state-of-the-art facilities to conduct research, but continuous re-investment in these facilities will be required to maintain top quality research. An additional issue is the substantial urban development in close proximity to the Arkell swine unit, which will likely force a relocation of this pork production oriented research facility within the next 5 to 10 years.

Table 1. Listing and brief description of the main public pork research facilities in Ontario.

Animal Holding Facilities	Brief Description
Arkell Swine, Guelph	This is a closed herd with about 300 sows, and a minimal disease unit with capacity to raise about 50% of offspring to market weight. This is the main unit for production type research and was built in the early 1980's. After too many years of rather serious neglect, substantial renovations are now being conducted. Recent renovations include the installation of a group housing system for gestating sows, the liquid feeding research unit, and a unit for management of genetically modified pigs.
Swine herd Ridgetown College, Ridgetown	A closed herd farrow-to-finish unit with about 70 sows for production type research. Some of the growing-finishing pens are equipped with computerized equipment to monitor growth and feed intake of group housed pigs. This unit is closely tied-in with research on manure processing technology.
Animal isolation unit at the Ontario Veterinary College, Guelph	This unit has strict biosecurity and allows researchers to expose small groups of pigs to highly infectious diseases and study their impact on the animals and alternative intervention strategies.
Ponsonby research station, Ponsonby	This flexible unit can accommodate various animal species and has no permanent pig herd. The unit has three identical and completely separate rooms that can accommodate weaned or growing-finishing pigs sourced from different genotypes or health status.
Animal metabolism unit, Department of Animal and Poultry Science, Guelph	This facility includes a surgery unit, facility to maintain surgically modified pigs for intensive and detailed animal metabolism studies, small rooms that allow close control of environmental conditions (temperature, airspeed, humidity), and facilities for housing boars for studying reproductive technologies.

continued (over)

General Laboratory Facilities

Meats Laboratory	This animal slaughter, carcass and meat processing facility is the only federally-inspected meat packing plant within a Canadian university. This facility supports teaching and research facilities for all aspects of meat science. It was built in 1980. Currently efforts are underway to upgrade this facility.
Laboratory Services Division, University of Guelph, Guelph	With a staff of more than 150 professionals this division is dedicated to providing a wide range of analytical services, including analyses of nutrients, toxins, blood parameters, chemical contaminants, genetic material (DNA) and microbes. It includes the Animal Health Laboratory, a full-service, fully computerized veterinary diagnostic laboratory.
Genome Manipulation Laboratory (GML)	The GML is a genetic research facility in the Department of Animal and Poultry Science, which serves as a regional facility for the generation of novel food animals. The GML focuses on improving the health, productivity and environmental sustainability of animal agriculture by generating novel strains of livestock through transgenics and cloning. There are currently no other food animal research facilities of this kind in the Province of Ontario.
Canadian Research Institute for Food Safety (CRIFS)	This institute is dedicated to the generation of new knowledge through basic and applied research, to the training of scientists and to providing information and expertise applicable to all sectors of the food industry. CRIFS' goal is to improve safety and quality by providing sound scientific information, research and development, food safety alerts and technology. This Centre was established in 2002 and with support from various levels of government and the University of Guelph (www.uoguelph.ca/crifs/).

VALUE AND IMPACT OF RESEARCH

It is a challenge to objectively value the (financial) impact of research in commercial pork production. The main outcome of research is new knowledge that can provide the basis for new or refined production practices. In some instances the value of this new knowledge is not immediately apparent. For example, when the structure of DNA was first discovered by Watson and Krick in the 1960's, it was not foreseen that we would be able to characterize and manipulate DNA in such a manner that we are now able to identify animals with genetic defects and or to introduce novel genetically controlled traits into farm-animals (see examples in next section). Along the same lines, the team of Dr. Julang Li, a new professor in the Department of Animal and Poultry Science, has recently been able to produce stem cells from

pig skin (Dyce et al., 2004). Such stem cells may be induced into many different cell types that have different functions in the animals' body, and possibly in the human body. This fundamental research can have a range of practical applications, for example for rapidly multiplying pigs with favorable traits, introducing novel traits in pigs, or generating of tissues and organs for humans. Substantial further research is required before these practical applications can be realized.

In other instances, the practical or commercial value of research is more apparent. For example, when the available nutrient content in pig feed ingredients is characterized more accurately feeding cost and nutrient losses into the environment can be reduced (Fan et al., 2001). In other research at the University of Guelph, a better understanding of the negative impact of feeding mycotoxins to pigs has resulted in intervention strategies when mycotoxins contaminated feed ingredients have to be fed to pigs (Smith et al., 2005). At the University of Guelph it has also been shown that feeding specific combinations of acids or essential oils to starter pigs can support similar levels of growth performance as compared to in-feed antibiotics (Namkung et al., 2004). Based on on-farm experiments, researchers from the University of Guelph have fine-tuned recommendations about the water and environmental needs of weaned piglets, resulting in improved pig growth performance (de Grau et al., 2005). In veterinary science, the development of diagnostic tests for pig diseases at the University of Guelph will lead to better health management and improved animal productivity (Corzo et al., 2005). Results of research projects that are currently underway at the University of Guelph are provided in the next section.

Economists have conducted cost-benefit analyses of investments in pig and pork research. For example, Dr. Glenn Fox from the Department of Agricultural Economics at the University of Guelph and colleagues at Guelph and Agriculture and Agri-Food Canada, have estimated the cost-benefit ratio of both public and private research that support pork production practices in Canada to be very high at 22.4 to 1 (Thomas et al., 2001). This estimate is based on careful assessment of research support from the various levels of government and the private sector, and the impact of research on production costs, consumer demand, and prices. Clearly, financial support of research in pork production practices is a very good investment.

In addition to new knowledge that results in improvement in pork production practices, research has various important other outcomes. In the process of conducting research, new researchers are trained and young individuals are exposed to the basic principles of science. Many of the people that are exposed to research will apply their knowledge and skills while working in commercial agriculture. Increasingly research is required to support policy development and establishment of guidelines for best management practices. In particular, in the areas of food safety, environmental impact, and animal welfare, solid methodology and benchmarks need to be established for an objective assessment of pig and pork production practices. Finally, researchers can be an important resource in times of major emergencies. We are all aware of the high costs of the foot and mouth disease outbreak in the United Kingdom in 2001. The severity of the outbreak would have been reduced if more researchers and well-trained veterinarians had been involved in the initial stages of this catastrophic epidemic. This is stated clearly in a report prepared for the British Department of Environment Food and Rural Affairs in 2005: "Swift implementation of the revised

contingency plan, in particular the mobilization of sufficient resources to meet key disease control targets such as effective tracing of dangerous contacts and rapid culling of infected premises and dangerous contacts” is a key determinant of the costs of outbreaks of diseases such as foot and mouth (Defra, 2005). Now that contingency plans are updated regularly, the costs of potential future outbreaks of foot and mouth disease in the UK are expected to be much lower than in 2001.

The benefits of training highly skilled individuals, research in support of policy and guidelines, and the ability to respond rapidly during crises are difficult to express in financial terms, but are all critical components of a successful and sustainable Ontario pork industry.

SELECTED RESEARCH HIGHLIGHTS

There is a long and impressive track record of high quality pig and pork research at the University of Guelph. It is clearly beyond this paper to highlight all important research findings. Only few examples are given below. For further information please visit the pork research website at the University of Guelph.

Four examples of older key research projects at the University of Guelph, and that have still important implications in today’s pork production practices, are the establishment of procedures to establish specific-pathogen-free (SPF) pig units, understanding of toxic effects of pathogenic *E. coli* strains (Gyles, 1994), the discovery of the gene responsible for porcine stress syndrome (PSS) gene (O’Brien et al., 1993), and the application of advanced mathematical procedures to assist in the development of pig breeding strategies (Kennedy et al., 1986).

In the 1950’s, researchers at the Ontario Veterinary College under the leadership of Dr. Chuck Roe established procedures to generate and manage pigs with extremely low loads of pathogens, known as SPF pigs. Dr. Paul Miniats, who ran the SPF laboratory at the University of Guelph from the late 1960’s through to his retirement in the late 1980’s, greatly improved the procedures. The procedures involve obtaining new-born piglets based on caesarian section and raising new-born piglets in clean environments without access to the sows. These procedures have been adopted by pig breeding companies in Ontario and around the world, and have been an integral part of studying infectious disease - such as atrophic rhinitis, Glasser’s disease, and pleuropneumonia - in gnotobiotic pigs.

Dr. Carlton Gyles gained a worldwide reputation for his research on the enterotoxigenic effects of *E. coli*, one of the main gastro-intestinal diseases in weaned pigs. Dr. Gyles recently retired from the University of Guelph, but he is still actively involved in research. Research on this topic is now also led by a Dr. Patrick Boerlin, a new faculty member at the University of Guelph, and is focused on relationships between anti-microbial resistance and disease causing properties of *E. coli* strains. This research program continues to lead to the development of intervention strategies, including the development of vaccines against pathogenic *E. coli* strains.

The discovery of the PSS gene and the development of a probe to detect the gene in individual pigs have been key developments to removing an important contributor to pale soft exudative (PSE) pork from many pig breeding herds and thus the entire pig population. The University of Guelph is still receiving royalties from this discovery.

The late Dr. Brian Kennedy was one of world's leading pig geneticists. His research has been the foundation for the application of advanced mathematical procedure (best linear unbiased predictor, BLUP) to pig breeding strategies. This procedure allowed the establishment of genetic links between different herds and test-stations and objective comparison of genetic merits of individual pigs that are raised on a large number of pig farms. Procedures based on BLUP are still the basis for breeding decisions in all major pig breeding organizations and used in pig breeding research at the University of Guelph, which is now led by Dr. Andrew Robinson. The early adaptation of BLUP and SPF technologies in Ontario are among the main factors that have contributed to the strong position of pure-bred pig breeders in Ontario, and thus the entire Ontario pork industry. These four examples also illustrate that progress needs to be made in fundamental science in order to develop practical application of new knowledge, as was discussed in the previous section.

More recently, the University of Guelph has been among the first institutions from around the world to generate genetically modified pigs (Golovan et al., 2001). In this research program, led by Dr. Cecil Forsberg, pigs have been trademarked as the EnviropigTM. These genetically modified pigs have been a substantial scientific achievement and have lead to research evaluating alternative means to introduce novel traits in pigs, and evaluating food and environmental safety associated with the use of genetically modified food-producing animals. An additional component of this research is to understand the public's perception of foods that are derived from genetically modified animals.

A small sample of findings in current research projects and that have immediate application in commercial pig and pork production is given below. The project numbers are registration numbers under the OMAFRA and University of Guelph research partnership program and can be accessed via in internet (www.uoguelph.ca/research/omafra/animals/pork.shtml).

- A rapid molecular biology based test has been developed to characterize Salmonella in a large number of samples (lead researcher Dr. J. Gray; Project #026207). This will allow for effective monitoring of Salmonella prevalence on Ontario farms and in pig slaughter houses, and to evaluate the effectiveness of intervention strategies.
- The sentinel herd health monitoring projects that was established in 2001 provides a unique resource to monitor the prevalence of disease and the dynamics of disease spreading on Ontario farms (lead researcher Dr. R. Friendship, project #026301). In this project it was established that a new strain of influenza virus (H3N2; different from the bird flu virus) has been spreading rapidly between farms since 2004. This project has been expanded to characterize and reduce the spreading and virulence of circo-virus under the leadership of Dr. C. Dewey (project #026303). This information will be essential for the development of effective disease management or elimination strategies.
- The group housing system at Arkell supports similar levels of performance as compared to conventional gestation stalls, while the group housing system benefits well-being of sows

(lead researcher T. Widowski, project #026181). Research on this system is continuing and is now focusing on the impact of timing of introducing new sows into the group system on reproductive performance.

- On several commercial sow units the use of artificial insemination (AI) is still associated with poorer farrowing rates, while several opportunities exist to improve reproductive performance with AI (lead researchers R. Friendship, C. Dewey, G. Cassar and M. Buhr, project #026289 and #026294). On several farms the fluctuations in temperature in the storage unit is more than 2°C or the temperature is outside the optimum range (15 to 20°C) leading to compromised semen quality. Timing of inseminations, use of injectable porcine luteinizing hormone following equine chorionic gonadotrophin to induce ovulation, and the mixing of frozen semen with seminal fluid of fresh semen are all important determinants of successful application of AI.
- In growing pigs, the impacts of body weight, dietary lysine and fiber levels, feeding frequency, between-pig variability, and compensatory growth on lysine utilization have been established (lead researcher Dr. C. de Lange, project # 026317). This information will allow for accurate estimation of lysine requirements of growing pigs at various stages of growth. Lysine is the first limiting amino acid and is linked directly to dietary protein, the 2nd most expensive nutrient in pig feeds.
- The availability of phosphorus has been established in a wide range of pig feed ingredients using a novel true digestibility assay (lead researcher Dr. M. Fan, project #026319). This project is expanded to evaluate calcium availability, to explore the impact of dietary calcium on phosphorus utilization, to identify biological indicators of phosphorus status that can be used to quickly establish whether phosphorus intake exceeds requirements in specific groups of pigs, and to pre-soak phytate containing ingredients with phytase enzyme in liquid feeding systems (project # 025997). Improved phosphorus utilization will both reduce the environmental impact of pig production and reduce feeding costs.
- Temporary restriction of feed intake in growing pigs and allowing pigs to express compensatory growth results in improvements in meat tenderness (lead researcher Mr. P. McEwan at Ridgetown College, project # 026278).
- There is large between-animal and between-farm variability (3 to 12%) in drip losses from loin and ham muscle sample (project leader Dr. P. Purslow, project # 026176 and 026358). These drip losses represent a substantial loss to the meat packers, and thus to the entire pork production chain. The large variability indicates room for improvement. Identifying means to enhance various aspects of meat quality and to reduce variability is the main objective of a new large and multi-disciplinary research program at the University of Guelph.
- When a stock person walks the pig pens only twice a week, pig behavior is influenced significantly (project leader Dr. T. Widowski, project # 026314). Walking the pen means that a stockperson enters the pen holding a pig board and makes one circuit around the pen in 20 to 40 seconds. Changes in pig behaviour resulted in easier and faster movement of pigs at the slaughterhouse. Relationships with meat quality are now being explored.

This short list of examples highlights the substantial and immediate commercial value of pig and pork research at the University of Guelph. It should be stressed that these applied research projects are often logical extension of more fundamental research. For the long-term

success of any research program an appropriate balance between fundamental and applied research must be maintained.

CONCLUSIONS AND FUTURE PERSPECTIVES

Researchers at the University of Guelph and the Ontario pork industry share similar overall and long-term goals, i.e. sustainable production of high quality foods in a globally competitive market place. At the University of Guelph a research program is in place that addresses research goals and objectives that have been established based on industry-wide consultations. Within this research program there is ample opportunity to explore innovative ideas and fundamental research, while addressing issues that are relevant to the Ontario pork industry.

The nature of research is changing and is now focused on food safety, pig well-being, minimizing environmental impacts, the public's perception of pork production, as well as pork production efficiency. With the advancement of science, new technologies have become available that involve molecular biology, genomics, genetic manipulation, proteomics, nanotechnology, and advanced mathematics. The use of these technologies will improve our understanding of underlying biological principles and will ultimately lead to improvements in pork production efficiencies and higher and consistent quality of pork products that meet the consumers demand.

High quality pig and pork research is expensive and requires focus on specific aspects of animal biology. As a result, it is not realistic that high quality research is conducted in Ontario on all key aspects of pork production. Therefore, research needs to be conducted in partnership with other organizations, such as Agriculture and Agri-Food Canada, commercial companies and indeed institutions from around the world. In order to establish and maintain such research partnership with leading research centres around the world it is important that the University of Guelph maintains its critical mass, research infra-structure, and strong reputations in key areas, such as health management, animal behaviour, reproductive physiology, molecular biology, nutritional biochemistry, and meat science.

The University of Guelph no longer has a mandate for traditional extension activities. Moreover, greater demands from the society at large and reductions in available resources have forced OMAFRA to focus more on policy development and alter its approach to extension activities. As a result, the University of Guelph and OMAFRA rely increasingly on industry partners, such as veterinarians and feed industry personnel, to facilitate the application of new knowledge in commercial pork production.

Objective measurement of the financial impact of research in commercial pork production is difficult. However, studies by economists have shown that the cost-benefit analyses of investments in pork research in Canada are very favourable at 22.4 to 1. Moreover, research activities contribute to the training of highly skilled personnel, provide information for the establishing of policy and guidelines for pig and pork production practices, and provide some

infrastructure for dealing with unforeseen emergencies that may arise, such as outbreaks of highly contagious diseases.

Clearly, the pork production industry is an important contributor to Ontario's economy. A healthy, profitable and sustainable industry that generates safe and high quality pork products will benefit Ontarians and Ontario's trade balance. New knowledge will continue to be required to support our industry. Continued public and industry support will become increasingly important to maintain a solid research infrastructure in Ontario, to train people that will contribute to the Ontario pork industry, and to respond to new challenges that may arise in the future. All members of the Ontario pork industry, including researchers, need to continually strive towards a fast and effective implementation of research findings in pig and pork production practices, and to be responsive to emerging challenges and opportunities. Feedback to the research at the University of Guelph is welcomed.

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APPENDIX 1

Research projects that are currently registered under the University of Guelph and OMAFRA Research Partnership Program, organized by research objectives and goals.

For more information on individual projects visit the OMAFRA website (www.uoguelph.ca/research/omafra/animals/pork.shtml), or contact the lead researcher or the coordinator of pork research at the University of Guelph (C. de Lange).

OBJECTIVE 1: STRATEGIES TO ADDRESS ENVIRONMENTAL ISSUES

Goal 1.1. Manure handling, including dead stock disposal

025983 – Emissions from cremation of dead stock – B. van Heyst, School of Engineering

Goal 1.2. Reduction of nitrogen and phosphorus excretion

026015 - The Enviropig: from the research lab to the market place - J. Phillips, Department of Molecular Biology and Genetics.

026082 - Modulation of intestinal fermentation and nutrient utilization for reducing detrimental effects on the environment from swine production – M. Fan, Department of Animal and Poultry Science.

026276 - Determining sow performance and mineral requirements with phytase supplementation of the lactating sow ration – P. Luimes, Ridgeway College.

026317 - Quantitative representation of nutrient utilization in the growing pig – C. de Lange, Department of Animal and Poultry Science.

026319 - Determination of dietary true digestible calcium to phosphorus ratio and requirements in weanling piglets (10-20 kg) fed corn and soybean meal-based diets – M. Fan, Department of Animal and Poultry Science.

Goal 1.3. Reducing Odour

026001 - Biofiltration as a means of odour and dust control in animal housing facilities – M. Dixon, Department of Environmental Biology.

026177 - Development of a pork farm odour expert system and studying the feed effects on odour – S. Yang, School of Engineering.

OBJECTIVE 2: PORK QUALITY AND SAFETY

Goal 2.1. Food safety

026207 - The natural transmission of *Salmonella typhimurium* in swine with and without antimicrobial selective pressure – J. Gray, Department of Pathobiology.

026273 - Evaluating effectiveness of interventions against *Salmonella* in swine using a novel evidence-based tool – S. McEwen, Department of Population Medicine.

026282 - Effect of bacteriophage on the population dynamics of *Salmonella* within Ontario pig herds – K. Warriner, Department of Food Science.

Goal 2.2. Reducing antibiotic use

026180 - Molecular analysis of important bacterial pathogens of swine – J. MacInnes, Department of Pathobiology.

026083 - Efficacy of alternative growth promoters for weanling piglets as assessed by visceral organ protein turnover rate – M. Fan, Department of Animal and Poultry Science.

026173 – Dietary means to enhance gut health of newly-weaned piglets – C. de Lange, Department of Animal and Poultry Science.

026272 - Spatial patterns of antimicrobial resistance among pig farms in southern Ontario. – O. Berke, Department of Population Medicine.

026291 - Genetic markers of infectious disease resistance in Ontario swine - A. Brooks, Department of Pathobiology.

Goals 2.3 and 2.4. Improving pork quality and uniformity of carcass

025981 - The effects of feeding high protein corn to pigs based on performance and carcass quality – P. McEwen, Ridgetown College.

026038 - Grow-finish pigs - Improving carcass quality through barn-level parameters analyses – C. Dewey, Department of Department of Population Medicine.

026059 - Quantitative and molecular genetic improvement of swine – A. Robinson, Department of Animal and Poultry Science.

026174 - Development of genetic markers for boar taint – J. Squires, Department of Animal and Poultry Science.

026176 - Development of nutritional strategies to improve the processing and eating quality of pork – I. Mandell, Department of Animal and Poultry Science.

026278 - The effects of gender and feeding strategy on pig growth performance and feed digestibility – P. McEwen, Ridgetown College.

026314 - On-farm management strategies to improve handling, reduce stress and enhance meat quality – T. Widowski, Department of Animal and Poultry Science.

OBJECTIVE 3: TO IMPROVE PRODUCTION EFFICIENCY

Goal 3.1. Feeds, feeding and mycotoxins

025997 - Liquid feeding of swine: gut health, food safety, environmental impact and growth performance – C. de Lange, Department of Animal and Poultry Science.

026171 - The use of byproducts from dry mill ethanol production as a feed ingredient in swine diets – P. McEwen, Ridgetown College.

026276 - Determining sow performance and mineral requirements with phytase supplementation of the lactating sow ration – P. Luimes, Ridgetown College.

026277 - Improving piglet survival by development of a hormone model of lactation – P. Luimes, Ridgetown College.

026278 - The effects of gender and feeding strategy on pig growth performance and feed digestibility - P. McEwen, Ridgetown College.

026317 - Quantitative representation of nutrient utilization in the growing pig
- C. de Lange, Department of Animal and Poultry Science.

026323 - Effect of Fusarium mycotoxins on performance and metabolism of gestating and lactating sows – T. Smith, Department of Animal and Poultry Science.

Goal 3.2. Improving pig health

026005 - Enteric disease control in post-weaned pigs – R. Friendship, Department of Population Medicine.

026068 - Modulation of host cell responses by porcine reproductive and respiratory syndrome (PRRS) virus – D. Yoo, Department of Pathobiology.

026170 - Phenotypic immunological imprinting by the neonatal environment in pigs – B. Wilkie, Department of Pathobiology.

026175 - Tetracycline use and selection of virulent enterotoxigenic Escherichia coli (ETEC) – P. Boerlin, Department of Population Medicine.

026277 - Improving piglet survival by development of a hormone model of lactation – P. Luimes, Ridgetown College.

026291 - Genetic markers of infectious disease resistance in Ontario swine

- A. Brooks, Department of Pathobiology.

026316 - Production of transgenic pigs that are more resistant to diseases

- J. Li, Department of Animal and Poultry Science.

Goal 3.3. Improving reproductive performance

025670 - PRRS virus: the implications for the breeding herd – C. Dewey, Department of Population Medicine.

026013 - A study of oxytocin-producing reproductive centres in the hypothalamus of the pig brain – G. Partlow, Department of Biomedical Science.

026179 - Analysis of transient lymphocyte functions in implantation sites during early pregnancy – A. Croy, Department of Biomedical Science.

026277 - Improving piglet survival by development of a hormone model of lactation – P. Luimes, Ridgetown College.

026289 - Improving swine reproductive performance through improved semen quality and better methods of insemination – R. Friendship, Department of Population Medicine.

026294 - Use of soy liposomes for cryopreservation of boar semen – M. Buhr, Department of Animal and Poultry Science.

026318 - Sexing of boar sperm using single stranded DNA aptamers
– S. Golovan, Department of Animal and Poultry Science.

026323 - Effect of Fusarium mycotoxins on performance and metabolism of gestating and lactating sows – T. Smith, Department of Animal and Poultry Science.

Goal 3.4. Transgenics

026036 - Artificial insemination mediated modification of pig genome
– S. Golovan, Department of Animal and Poultry Science.

026316 - Production of transgenic pigs that are more resistant to diseases
- J. Li, Department of Animal and Poultry Science.

OBJECTIVE 4: TO IMPROVE ANIMAL WELL-BEING

026069 - Meeting the needs of ill swine to improve well-being and decrease reliance on antimicrobials - S. Millman, Department of Population Medicine.

026081 - Developing a comprehensive framework to assess farm animal welfare – S. Henson, Department of Agriculture Economics & Business.

026181 - Strategies for reducing aggression in loose housed sows
– T. Widowski, Department of Animal and Poultry Science.

026182 - Management practices affecting the behaviour and welfare of piglets
- T. Widowski, Department of Animal and Poultry Science.

026304 - Factors associated with transport losses in market weight finisher pigs
- C. Dewey, Department of Population Medicine.

HANDLING DISEASE CHALLENGES

DIFFERENT APPROACHES TO HANDLING PRRS

Monte McCaw
Pig Health and Production Group
Population Health and Pathobiology Department
College of Veterinary Medicine, North Carolina State University
4700 Hillsborough St, Raleigh, NC 27606
E-mail: monte_mccaw@ncsu.edu

ABSTRACT

Developing methods to control PRRS is both a critical and long-standing challenge for the swine industry. To quote Dr. Mark Fitzsimmons, Swine Graphics, Webster City, Iowa: ***Abasic PRRS virus information, particularly in the area of immunity and transmission, is conspicuous by its absence.*** In short, there is a lot we do not know yet about PRRSV and hence its *predictable* and *effective* control which I wish I could share with you today. However, we have come a long way from the days of Mystery Swine Disease, Abortus Blau, Porcine Epidemic Abortion and Respiratory Syndrome, and EMC virus. **PRRS control strategies that work have been developed**, each however usually limited to specific types of situations and production types. This presentation will attempt to clearly define essential concepts of PRRSV-pig “biology” and then review control strategies for PRRS, both conventional and unconventional. It is by necessity only an overview, hopefully providing a clear basis and framework for weighing different approaches to PRRS control. For more details on PRRS control I strongly urge you to read the applicable sections of the Producer Edition of 2003 PRRS Compendium produced by the National Pork Board (United States) and edited by Drs. Zimmerman, Yoon, (Iowa State University) and Neumann (National Pork Board). This is an excellent document which provides a practical review of scientific knowledge as well as current, albeit untested methods used for controlling PRRS (scientific proof often follows practical and effective innovations).

For a more detailed review of current scientific knowledge read the 2003 PRRS Compendium, second edition. Both are available (for \$30US) in a single CD from the US National Pork Board at:

<http://porkstore.pork.org/customer/product.php?productid=202&cat=260&page=1>.

PRRSV-PIG “BIOLOGY” AND IMMUNOLOGY

PRRS is particularly a disease of LARGE three-site or single-site swine herds which use management short-cuts that don’t meet the needs of the pigs or designs which compromise both internal and external biosecurity.

Continuous flow rooms, buildings, and possibly sites, as well as breeding barns which receive susceptible gilts regularly enable **continuous virus replication** (constant source of susceptible pigs), **holding-back** of poor-doers (Typhoid Marys), short time for cleaning,

disinfecting, and DRYING of rooms and transports, inadequate isolation and testing of breeding stock, semen, inadequate pre-immunization of breeding replacements prior to entry, etc, etc, etc. Continuous virus replication enables maximum PRRSV mutation and ultimately “escape” from the herds’ initial immune responses. Typhoid Mary **hold-backs infect younger groups of pigs**, ensuring they repeat the same PRRSV-associated disease-losses of their predecessors.

Definitions:

Modified-Live Virus (MLV): PRRSV which has been altered in the laboratory to reduce its virulence or pathogenicity in an effort to make it safe(r) for use as a live-virus vaccine.

Virulent Live Virus (VLV): **Unaltered** or Wild-Type PRRSV isolated from a diseased pig. VLV can be grown and multiplied unchanged in Porcine Alveolar Macrophage (PAM) cultures, from blood or lung tissue from purposefully infected PRRSV-free pigs, or from diseased pigs within herds during PRRS outbreaks. In the last case, it is imperative to collect the blood or tissues from febrile aborting sows or weak-born febrile piglets if it is to be used later to immunize / acclimatize gilts in isolation or perform whole-herd exposure and closure (see below).

Horizontal infection (transmission): PRRSV infection comes from another pig of the same age or production group (all-in all-out flow) or within the same room where pigs of different ages are housed together (CF production ***and breeding herds***). Virus transfer occurs by exchange of saliva, blood, or semen. Therefore, **mixing pigs** from different litters or pens (causes fighting and exchange of saliva and blood) or **not changing needles or blades** between litters, pens, or at times pigs, ***helps horizontal transmission***. We all know the impact PRRSV-infected semen can have!

Vertical infection (transmission): PRRSV infection comes from the sow either ***in utero*** (across the placenta ~ **70 days at the earliest**) or from milk, oral / nasal contact. ***In utero*** infection has the most severe impact on piglet immune system and duration of (persistent) PRRSV infection.

Persistent infection or “persistence”: Ability of PRRSV to stay in an infected pig for weeks and months after infection. PRRSV may persist in these pigs, be shed, and infect other pigs over 80 to 100 days (maybe longer??). Persistence seems to be a result of a slowed development of FULLY protective immunity (ability to eliminate the virus) by some unknown effects of PRRSV on the pig. PRRSV persistence after infection is the reason recommendations are made for both long periods of time for herd closures when attempting herd virus elimination or for duration of isolation during acclimatization after exposing new gilts to VLV.

PRRSV BIOLOGY

Post-infection PRRSV “timeline”: (Long time needed to develop “full” immunity / clear PRRSV infection)

Days post-infection

10 – 30	Viremia (virus can be isolated from blood), strong PRRSV ELISA antibody response.
20 – 30	Earliest time neutralizing antibody can be detected in blood
60+	Full or peak titer of neutralizing antibody in blood reached
100 – 150	Tonsil / Lymph Nodes become PRRSV negative (nursery infection)
100 – 150	Many pigs become PRRSV ELISA negative (< 0.4 S/P ratio), still SN+.
150++	Tonsil / Lymph Nodes become PRRSV negative (<i>in utero</i> infection)
200	Duration of herd-closure needed post-outbreak to eliminate PRRSV from the herd.

If total, fully-protective immunity (elimination of PRRSV from ALL tissues of the pig) requires up to 150 days after infection, then this “fact” may explain why piglets born to gilts are the most likely to be PRRSV-infected *in utero*. Endemic PRRS most likely results from gilt litter *in utero* infected piglets carrying the virus for months and subsequently infecting the rest of the pigs in their production group and causing disease losses in either the nursery or finisher phase. This hypothesis would also explain the success of Parity Segregation production for eliminating endemic PRRS in piglets born to sows in the P2+ herds, limiting endemic PRRS to only the P1 gilt herd pig flow.

PRRSV IMMUNE RESPONSES:

TO PROTECT or NOT TO PROTECT, *THAT* is the QUESTION

Introduction: The ability of pigs to produce protective immune responses to PRRSV infections that can also “cross-protect” against other “strains” of the virus often appears limited or even non-existent. The anti-PRRSV immune response seems “narrow” in scope, potentially much like the HIV of AIDS and its cousin, Feline Immunodeficiency Virus. This poor ability to cross-protect possibly is due to a relatively high rate of genetic mutation (changes in genetic sequence) which results in far more “strains” (viruses that don’t cross-protect) than even Influenza viruses. Therefore PRRSVs are nearly impossible to “immunologically categorize” or predict cross-protection between since 1) the mechanisms needed for protection are poorly understood, 2) the location of the targets of immune responses are unknown, so 3) we don’t know which mutations or changes in genetic sequence are important! PRRSV immunity is often discussed in scientific terms, common descriptive terms, and *hybrid combinations of both (slang)!* This common verbal practice of veterinarians and veterinary “scientists” adds to the frequent and sometimes serious confusion that we all experience when talking about control of PRRSV.

PRRSV Immune Response Definitions:

Homologous PRRSVs are two virus isolates tested in the laboratory which have the SAME GENETIC SEQUENCE.

Heterologous PRRSVs are two virus isolates tested in the laboratory which have DIFFERENT GENETIC SEQUENCES. By definition they can differ by a couple of

mutations (> 99.5% “homology” or “sequence sameness”), or many, many mutations (<85% “homology”). The degree of difference or “heterogeneity” plays a role in the amount of cross-protection against disease between PRRSV isolates. **HOWEVER, “% genetic homology” between two PRRSV isolates cannot be used what-so-ever to predict protection!** This is because % homology does not include any information about the LOCATION of the mutations or genetic differences, i.e. are they located in immune response target genes.

Protected pigs: Pigs and pregnant sows which are totally resistant to disease when challenged or injected with live Wild-Type PRRSV. The most complete and only predictable protection is **against the same or homologous WT PRRSV.**

Susceptible (unprotected) pigs:

1. Naïve or uninfected pigs are obviously susceptible to disease following WT-PRRSV infection.
2. **WT-PRRSV immune pigs can be very susceptible to disease with a new, genetically-different or “heterologous” WT-PRRSV!!!**
3. ***Vaccinated pigs also can be very susceptible to WT-PRRSV infection and disease!*** infection. By definition, Modified-Live Virus vaccines are genetically-different or heterologous to all WT-PRRSVs.
4. Susceptibility is the opposite of protection against PRRS disease. There is a **full-spectrum of pig responses to heterologous PRRSV infection** ranging from full protection (we never know the pigs were exposed) to no protection / full susceptibility and severe disease. To date, we cannot predict the amount of cross-protection between two different PRRSVs by comparing their genetic sequences. We do not know where the targets of any Cell-Mediated Immune responses are for PRRSV. We do know where at least one target is of serum-neutralizing antibodies. Measuring the cross-neutralizing ability of serum neutralizing antibody against the heterologous PRRSV may provide some information about cross-protection.

PRRSV strains are virus isolates which are **1) genetically different** or *heterologous* and **2) immunity against one does not cross-protect “well” against the other.** One isolate stimulates immune responses which do not cross-protect against clinical disease following challenge of immune pigs with the other heterologous isolate. The most extreme types of heterologous strains were the Acute PRRSVs which caused severe disease initially in frequently vaccinated herds in 1996 – 1998, and again from 2001 - 2004 in Wild-Type PRRSV-immune herds in the US. There is currently no exact definition of how severe the clinical disease should be, what specific clinical signs or neutralizing antibody / immune response test outcomes to conclude there is a “lack of cross-protection” between two isolates. Regrettably, this conclusion is only established retrospectively, i.e. after a severe PRRS outbreak and economic loss occurs following mixing two groups of pigs, sows and replacement gilts, or using semen infected with a heterologous PRRSV.

Subpopulations are subgroups of sows or gilts in the sow herd which are susceptible to PRRSV infection (naïve) or re-infection (lost their protective immunity). They have low or no immunity against PRRS. All animals in a PRRSV infected herd can be susceptible to

infection and disease by a new and DIFFERENT enough strain of PRRSV. Subpopulation has become a slang term which has clear meaning when discussing naïve, non-infected groups of pigs within a herd such as newly introduced “negative” gilts. The meaning of subpopulation becomes less clear when discussing animals that have “lost their immunity” to the herd’s original or “homologous” PRRSV. Lastly, there may be “subpopulations” of pigs or sows within a “positive” herd following a disease outbreak caused by introduction of a second, different, heterologous PRRSV “strain”.

PRRSV immunity (protection) “slang subtypes”:

Homologous immunity is produced against the same PRRSV isolate or strain that initially infected the pig. It is generally thought that this immunity is long-term, however, it may not be life long. Homologous immunity is the highest level of immune response efficacy a pig can produce, i.e. protection against re-infection with the same virus is almost total.

Heterologous immunity describes the protection pigs possess against challenge with a different virus strain. The “amount” of cross-protection provided by “heterologous” immune responses to heterologous virus challenge is often less than the “full cross-protection” seen of “homologous” immune responses to homologous PRRSV challenge. Sometimes it seems heterologous immunity is nearly nonexistent. The amount of heterologous immunity a virus can stimulate in a pig is probably due to how genetically similar that virus is to the new challenging strain of PRRSV, i.e. how few immune response targets on the different viral proteins have been mutated. The totally frustrating problem for veterinarians and scientists alike is that we do not know what virus genes must have identical sequences to stimulate fully cross-protective immunity.

PRRSV Immune Response Principles:

Relevance of Virus Genetic Sequence Homology to Producers and Veterinarians efforts to control PRRS: Typically, only PRRSV Open Reading Frame (ORF) 5 is sequenced and compared in Veterinary Diagnostic Laboratories. It “codes for” the major glycoprotein sticking out from the outer envelope or “shell” of the virus. **The ORF 5 sequences reported by Veterinary Diagnostic Laboratories describes only 4.4% of the whole PRRSV genome (~ 660 of 15,000 “base-pairs”).** This ORF 5 sequence data is used by veterinarians to track and compare PRRSV isolates within and between herds. There is a single known target of neutralizing antibody coded by ORF 5. However, there are probably many other unidentified and significant antibody and Cell-Mediated Immunity targets coded in ORF 5 and the other 7 parts or ORFs of the PRRSV genome.

Therefore:

1. ORF 5 genetic sequence data alone probably is very incomplete for prediction of cross-protective immunity between two virus isolates from different time-points within a herd or from different herds.
2. **We do not know where the key targets of antibodies or cell-mediated immunity are located even in ORF 5 (only one neutralizing antibody target in ORF5 is known).**
3. Predictions of cross-protection between vaccine and wild-type PRRSVs using

measurements of ORF 5 sequence “sameness” such as “RFLP cut-patterns” or % homology are nearly WORTHLESS.

There are field reports both of PRRSVs with very similar ORF 5 sequences causing severe disease problems and of viruses with 10% or more different ORF 5 sequences causing nearly no disease when infecting pigs known to be immune to the other virus (Dr. Mark Wagner, personal communication). Therefore, attempts to predict the amount of cross-protection between two PRRSV isolates by % genetic sequence homology is a frustrating exercise of ignorance and futility. Two viruses with identical ORF 5 sequences have the best chance of stimulating fully cross-protecting “homologous immune responses, but even this is not guaranteed if they came from different herds. Identical ORF 5 sequences from pigs in the same herd isolated at different times can be used to predict that they are / the herd is protected against that PRRSV. It is most likely, but not guaranteed, that these two PRRSV isolates would be very similar throughout their whole genomes.

PRRSV DIAGNOSTIC TESTS AND INFECTION MONITORING

Testing to confirm groups of pigs are virus-free is difficult with PRRS. Pigs can lose their ELISA antibody response by 4 to 6 months after infection, even when they are being re-exposed to the same virus isolate. Some pigs can be persistently infected (are PCR positive on tonsil scrapings) and be ELISA antibody negative. Pigs retain serum neutralizing antibody titers for much longer, however, mutations have been found in the SN antibody target that can cause serum samples to test false negative or very low titer. Therefore, antibody testing of large numbers of pigs is needed to make decisions on whether a group of pigs or herd is PRRSV-free. Enough PRRSV can be carried by just a few pigs at weaning to infect a finisher full of pigs, but yet remain undetected in the nursery if only 10 to 30 pigs are tested at 10 weeks of age. Testing 30 animals can reliably detect at least ONE PRRSV-infected animal **only if** more than 10% of the group is infected. Retesting and finding negative ELISA results repeatedly over time also increases confidence that the group of pigs / herd is PRRSV negative. Tonsil scraping and testing by PCR is the best antemortem test available for detecting persistently infected pigs. This may be a very valuable method for routinely testing critical animals which are entered in low numbers such as boars to boar studs. **To certify that a group of pigs is PRRSV-free, ALL ANIMALS must be tested and found to be antibody test and / or PRRSV PCR negative.**

PRRS CONTROL OPTIONS BY HERD STATUS OR PRODUCTION PROBLEM

Acute PRRS (outbreaks with both reproductive and growing pig disease losses)

PRRS clinical outbreaks are times of anger and despair. However, they are also times where critical decisions need to be made that may minimize both current as well as long term losses due to PRRS. To minimize piglet and weaned pig losses implement McREBEL (limited cross-fostering) management immediately (procedures attached). Optimal results may not be seen during the first couple of weeks of the outbreak if sows are sick, not eating well, and

therefore not lactating well. If piglets are not moved between litters you should see only some litters with sick, poor doing piglets in them. This allows you to focus intensive care and treatment toward fewer litters than if fostering is practiced. Success is expected by both reduced mortality and disease as well as most pigs being weaned with fat irregardless of their body weight. PRRSV can be spread by needles or other means of carrying blood (knife blades, etc). Therefore minimize treatment to only pigs and litters that need it. Do not use one needle to treat two or more litters, and treat affected pigs for up to 5 days. PRRS causes severe damage to the piglet's immune system and their ability to fight bacterial disease, therefore treatment is needed for longer periods of time. Euthanize any piglets that do not respond to treatment, do not move them into the nursery to infect other healthier pigs. If McREBEL is followed correctly, nursery pig mortality will also be reduced and gain maximized even though pigs are placed into nursery pens by size and sex. It is essential to follow strict all-in all-out pig flow from farrowing through finishing to minimize the risk or duration of endemic PRRS associated-diseases.

Critical decisions also must be made for the sow herd during PRRS outbreaks. Long-term problems with PRRS come from variations in immunity to the virus between sows within infected herds. PRRSV actually does not spread easily or uniformly through herds, especially previously infected and possibly vaccinated herds (personal observation of differences in seroconversion in various breeding groups). Groups of non-immune or susceptible sows remain after the outbreak has ended (subpopulations). These subpopulations are thought to be the source of new clinical outbreaks and losses once PRRSV starts to spread in the herd again and finally reaches these susceptible animals. Some veterinarians and producers therefore have chosen to make sure all animals are exposed to PRRSV during the outbreak. They 1) vaccinate the whole herd or 2) ensure exposure to the homologous WT PRRSV. Exposure to the homologous WT PRRSV can be done by 1) moving aborted animals around to all areas of the gestation and breeding barn, 2) feeding back tissues or inoculating with serum from aborted sows and/or weak-born viremic piglets, 3) purchasing and infecting 4-6 months of naïve replacement gilts, 4) closing the herd to new additions for 200 days (more if there are still viremic piglets being born).

The goal is to get all animals in the herd immune to the virus, to stop shedding the virus, and therefore to deny the virus any new, susceptible hosts to continue to multiply in. ***If we fail to stop the circulation (shedding by one sow resulting in infection of new sows) long term problems with PRRS (see below) will reoccur / continue in the breeding herd and nursery / finisher.*** Therefore, many veterinarians choose to ensure all animals get infected during the outbreak and close the herd as the currently most predictable, effective, and easiest way to achieve whole herd immunity to end both horizontal and vertical virus infection in the herd. Frequently they report that abortions and birth of weak PRRSV-infected piglets ends quicker and completely. ***This information is provided in an attempt to be complete and is not a blanket recommendation to or not to use virulent live virus exposure. This decision is a complex one and needs to be done on a herd by herd basis. Factors and methods to consider which are intended to minimize the risk of this approach are listed in a document in the appendix below.*** Previously infected herds need to quickly determine whether the current outbreak is due to infection by the original herd PRRSV or a heterologous one.

Decisions of whether to spread virus through the herd or what source of virus to use may be changed if a new, heterologous virus has infected the herd.

Success of whole herd commercial MLV vaccination during an outbreak depends upon how much the vaccine will cross-protect with the wild-type virus. Short-term success may be observed just because the clinical outbreak would have ended quickly as a result of rapid whole-herd infection and hence establishment of herd immunity, not because of MLV vaccination. Failure of MLV vaccination to control PRRS long-term following outbreaks may be due to a low level of cross-protection with the WT PRRSV that infected the herd. This would leave gilts vaccinated at or prior to entry into the herd susceptible to infection by the herd's WT PRRSV. Gilts would be infected by the herd's WT PRRSV (with or without clinical signs) sometime during gestation and their piglets potentially would become infected *in utero*. The *in utero* infected piglets from gilt litters would then carry the virus into the nursery and finisher ultimately infecting and causing endemic PRRS disease losses in their production group. If PRRS disease losses persist or return in the face of continued vaccination and the original outbreak virus is isolated from both affected pigs and gilt litter piglets, then the vaccine did not stimulate sufficient levels of cross-protective immunity against the herd's WT PRRSV, particularly in replacement gilts. In this scenario vaccination with a poorly cross-protective MLV vaccine allows the herd to progress into "endemic PRRS" and **long-term economic losses**. Ultimately, the decision to use MLV vaccine in sows or pigs must be made upon whether with it, you are profitable and without it, you are not. Many US producers have determined they cannot produce pigs profitably with any permutation of MLV vaccination schedules because the reductions in disease losses achieved was unable to stop continuation of significant economic losses. Therefore they have turned to methods known to stimulate full homologous immune responses throughout the breeding herd, or have decided to eliminate the virus from their herds and pray the herd is not reinfected.

Endemic PRRS (reoccurring nursery / finisher disease)

PRRSV and common secondary diseases often continue to reoccur in the nursery and finisher phases for a long time following PRRS outbreaks. This may be the result of either horizontal spread between groups (holding back poor-doing INFECTED / SHEDDING Typhoid Mary pigs to younger age groups, virus transfer by boots or veterinary tools, etc.) or from vertically infected piglets (infected *in utero* or during lactation) who then carry the virus into the nursery and finisher. To control and eliminate endemic PRRS you must identify where the virus is coming from (nursery group cross-contamination vs. sow herd virus circulation causing *in utero* PRRSV infection). The virus is from contaminated nursery rooms or holding back of sick pigs if no PRRSV is detected by PCR from newborn piglets, serologic testing of the sow herd shows no evidence for active spread, and there is no evidence of active PRRS disease in sows (abortions, early farrowing, increased % mummies, and weak viremic piglets). In this case successful elimination of PRRS disease can be accomplished by total nursery depopulation, partial nursery depopulation, or whole nursery / finisher vaccination in addition to partial depopulation. All pigs are recommended to be vaccinated twice, 30 days apart. Some vets recommend also closing the nursery and finisher to any new pigs for 60 days following the first vaccination. **Strict all-in all-out pig flow with very thorough cleaning and disinfection is essential to success of these programs.** Also, to further ensure success,

assign workers to only work with clean or PRRSV-infected pigs until the project is completed. If the finisher is affected, continue these methods through all buildings until all infected groups of pigs have been marketed. **Depopulation or vaccination programs cannot stop PRRS in the nursery or finisher if pigs are getting infected *in utero* or in lactation.** Suggestions for how to stop virus circulation in the sow herd and therefore vertical spread to piglets are discussed below.

Methods for Long-Term Control of PRRSV Infection in Sow Herds

Summary: Long-term control of PRRS in herds depends HEAVILY upon stopping circulation or spread of the virus between sows in the herd. **PRRS losses in growing pigs cannot be controlled if the virus is circulating among sows in the herd.** Newly added gilts or susceptible subpopulations of sows will get infected and transmit the virus to their piglets *in utero* or during lactation (vertical spread) if there is circulating virus in the breeding herd. The following Critical Control Concepts and Procedures are useful to fully understand the different methods used to control PRRS in sow herds.

IN ALL CASES Biosecurity Flaws must be found and fixed first if the herds are to successfully **control PRRS** (remain “stable” but infected and immune to a single WT PRRSV) or **eliminate PRRSV** for long periods of time.

Isolation, acclimatization, and cool down of incoming gilts is designed to immunize gilts against the herds’ homologous PRRSV. This should produce a homologous (“fully” protective) immune response against the WT PRRSV isolate in the herd. Acclimatization attempts to prevent the build-up of a subpopulation of animals in the breeding herd (gilts) which is susceptible to the herd’s homologous WT PRRSV. Obviously these animals would spark a new outbreak of disease if they subsequently get infected. To **acclimatize gilts in isolation** they can be exposed to non-pregnant cull gilts or sows (unreliable method for infection), nursery pigs (inconsistent infection of gilts and risk of severe PRRS outbreak by introduction of a mutated heterologous PRRSV), or inoculated with serum or lung tissue from infected suckling piglets. The intent is to infect and immunize ALL gilts with the homologous herd virus. An extended time for cool down (90 days in all-in all-out isolation) is needed to get past the persistent infection period where acclimatized gilts could still shed the virus to susceptible sows in the herd or possibly to their piglets *in utero*. This procedure is used in herds that have demonstrated that MLV vaccines do not provide adequate cross-protective immunity against their herd’s strain of PRRSV. This conclusion is established by consistently detecting WT PRRSV in suckling piglet serum which has an ORF 5 sequence homologous with virus isolates from the herd’s PRRS affected nursery and finisher pigs. **These producers are experiencing significant and sustained economic losses** resulting from severe endemic PRRS.

Vaccination with MLV vaccines is approved for use at least twice before entry into the herd / breeding and then during every lactation to try to control PRRS in both sows and their progeny. A new approach called mass vaccination is now being advocated to control virus circulation in the sow herd. It requires working with a veterinarian since the MLV vaccine is not approved for use in pregnant animals. The goal is to get sufficient herd-wide cross-

protective immunity to stop circulation of PRRSV among sows and therefore vertical infection of their piglets. The herd is vaccinated twice, 30 days apart and is closed to any new gilts for 60 days. The herd may continue to be mass vaccinated quarterly, or attempt to eliminate PRRSV by introduction of naïve non-vaccinated gilts. If elimination is desired, then the herd should be closed for 200 days (see herd closure below). The herd can then be checked by introducing and monitoring a few unvaccinated negative sentinel gilts to see if WT PRRSV and MLV virus circulation has stopped before starting routine introduction of naïve replacement gilts. Success of this approach, like all others, depends upon how complete the MLV immunity cross-protects against the WT PRRSV infecting the herd.

Killed PRRSV vaccine is safer because it can not shed to other animals in the herd. Killed vaccine is labeled for use in pregnant animals and therefore can be used without question in mass vaccination programs. Some producers have used mass vaccination with killed vaccine to stop virus circulation in the herd before starting PRRSV eliminations in their herds. There has been much debate with limited scientific evidence that killed vaccines can stimulate effective immunity alone. However, there are a couple of studies that indicate killed PRRSV vaccine appears to boost the immune response of pigs previously infected with live PRRSV. This effect may be dependent upon the % genetic homology between the herd's WT PRRSV and the killed PRRSV vaccine.

Success of any of the discussed vaccination options depends upon whether the vaccine is genetically similar enough to the herd virus to stimulate a protective immunity. Some wild viruses are similar enough that the vaccine will work, others appear not to be. The biggest frustration for veterinarians is that the information in PRRSV genetic sequence reports cannot be used to accurately predict whether vaccine will effectively cross-protect against the strain of virus infecting their client's herd (see above discussion).

Herd closure or depopulation / repopulation have been used to eliminate PRRSV from infected herds. Herd closure is most successful in farrowing only herds (no on-site nursery or finishing pigs) which have not had evidence of active PRRS reproductive disease or seroconversion in offsite nursery pigs for over a year. PRRSV-free sentinel gilts or vasectomized boars can be used to check the sow herd for PRRSV circulation before starting the elimination program. These herds are closed to new additions for approximately 140 days during which PRRSV free replacement gilts are bred offsite. The first of the offsite bred gilts are scheduled to farrow 6 weeks after the last of the on-farm bred gilts have farrowed. PRRSV free gilts are continually added and previously infected sows culled naturally until the herd is populated with only PRRSV-free sows. The biggest challenge is getting PRRSV to stop circulating in the sow herd before starting a herd closure project. This is very difficult in large herds, and herds which have onsite nursery or finishing pigs. In these cases total depopulation of the herd will eliminate PRRSV. If possible, depopulation of nursery and finisher buildings, subsequent sale of all weaned pigs and herd closure for 200 days may also successfully eliminate PRRSV from one-site production herds. Replacement gilts should be bred offsite to minimize the down time between farrowings. Depopulation appears to be the only viable option for herds infected with multiple strains of PRRSV where vaccination or gilt acclimatization has failed to control reproductive and finisher disease problems. Integrated

pig production company Production Managers estimate the costs of total depopulation can be recovered **if the herd can remain PRRSV-free for one year.**

Serum therapy or VLV immunization is a desperate yet logical procedure being used in herds to insure exposure of replacement gilts in isolation to acclimatize them to the herd's strain of WT PRRSV. It is a form of autogenous vaccination which is intended to ensure stimulation of homologous (full) immunity against the herd virus in a short period of time. This procedure is most effective and predictable in herds infected with a single strain of PRRSV. It is chosen by herds which are certain that all other options including vaccination cannot control their PRRS disease problems. This procedure has definite risk since gilts are being infected with live WT virus in the serum from infected pigs from the producer's herd. The greatest risk is bringing in inoculated gilts into the herd too soon such that they are still shedding the virus (still persistently infected) to sows or to their own piglets *in utero*. Additionally, the isolation /acclimatization unit must be run all-in all-out to minimize the risk of virus shedding gilts and continuous mutation of the herd's WT PRRSV. Other producers have considered using serum immunization of all sows in the herd during PRRS rebreaks (SAME virus causing reproductive disease that originally infected the herd) to make sure all sows are exposed, and all become immune simultaneously. This provides an opportunity for farrowing-only herds to eliminate PRRSV if 4 to 6 months of replacement gilts can be obtained, exposed to the outbreak virus, and the herd closed for 200 days. At the end of this time period negative sentinels are added to check for virus circulation. If no PRRSV circulation is present, then regular introduction of PRRSV-free gilts is started as described in Herd Closure above. **Serum immunization of pregnant sows will likely cause abortion in some later-term sows or gilts and also infection of piglets *in utero* that will probably cause PRRS-associated disease problems in the nursery and finisher.** This is a desperate measure to be considered only as a last resort. The amount of losses are difficult to predict, and should be weighed against the cost of depopulation of the herd. Elimination of PRRSV from the nursery and finisher sites will have to be accomplished, probably by depopulation or production breaks, to gain full economic benefit of herd closure following a re-break or initial outbreak.

Alternatively, the advantage of serum immunization is that during outbreaks, it ensures both a whole-herd exposure to the PRRSV and also brings a quicker end to abortions, weak-born and mummified piglets. In turn a quicker end to viremic groups of weaned pigs is achieved and thereby nursery / finisher pig PRRS losses. Therefore, while this process MAY increase the total number of aborted litters, it **ensures all sows are exposed at the same time.** Otherwise some sows in mid-gestation (feti apparently not susceptible) which do not initially get exposed, will become exposed later, now during late gestation when their piglets are susceptible to infection. These piglets, born into later production groups, will be viremic due to *in utero* infection, and will increase the number of production groups that are infected and affected by PRRS. Therefore, it has been observed that serum therapy or VLV inoculation of pregnant sows and 4 months of replacement gilts combined with herd closure during PRRS outbreaks will decrease BOTH the number of breeding groups that have abortions and certainly that have piglets infected *in utero*, ultimately stopping PRRS-affected production groups much sooner.

CONCLUSIONS

This presentation purposely does not advocate one control strategy over another. Decisions of which to use can be complex and must be tailored to each individual herd situation. Factors such as number of strains which infect the herd, breeding stock source(s) PRRSV status, availability of isolation and acclimatization facilities, density of pig production in your area, economic status of the herd, risk aversion (or desperation), production type / flow, herd size, biosecurity measures used, etc. need to be weighed. Decisions must be made based upon collection of all needed information to answer these and other questions. What makes PRRS challenging to control is that this information (herd PRRSV circulation status in particular) can change over time, and hence, affect which control methods to use and their likely success.

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APPENDIX

McREBEL

LIMITED CROSSFOSTERING PRODUCTION PROCEDURES

MONTE B. McCAW DVM PhD, monte_mccaw@ncsu.edu

- 1) **Don't crossfoster piglets after 24 hours of age**
 - a) move the minimum number of pigs necessary to load functional teats
 - b) don't crossfoster to create uniform size or sex litters
 - c) when EXTRA medium or large pigs must be moved, do match them by size and milking ability of receiving sows and litter
 - d) ensure smallest piglets are given lowest priority for functional teat assignment, leave on birth sow or move as Aextras@ when more piglets than available teats

MAXIMIZE THE NUMBER OF PIGLETS REMAINING ON THEIR BIRTH MOTHER!

Otherwise, maximize the number of piglets remaining on colostrum mother.

- 2) **Don't move piglets between rooms**
 - a) follow strict All In - All Out production

THE LITTER IS NOW THE ALL IN - ALL OUT UNIT!

- 3) **Remove very sick, moribund, or bad body condition pigs from the system**
 - a) sell or eliminate piglets at weaning that are too light to survive in the nursery and have poor body condition
 - b) eliminate immediately piglets that don't quickly get better after treatment
 - c) eliminate very thin, starve-out, lame, light body weight, long-haired, chronically sick piglets as they are found

A PIGLET HELD-BACK FROM WEANING TAKES A TEAT AWAY FROM A YOUNGER, POTENTIALLY HEALTHIER PIG!

- 4) **Nursery care practices to maximize piglet survival and performance**
 - a) size piglets into pens carefully
 - b) place smallest piglets in warm, non-drafty part of room
 - c) hand feed smallest piglets 4 times a day for 5 days
 - d) switch rations based upon weight of pen, not room
 - e) use heat lamps and / or plastic lying pads for small piglets
 - f) lower one nipple / pen and jam it open for the first 24 hours to help piglets find water.

DON'T EXPECT TO WEAN ANY MORE QUALITY PIGLETS THAN THERE ARE FUNCTIONAL TEATS IN A FARROWING ROOM.

TO MAXIMIZE THE NUMBER OF PIGLETS WEANED PER ROOM, MAXIMIZE THE NUMBER OF FUNCTIONAL TEATS BY PROPER GILT SELECTION AND SOW CULLING.

DIFFERENT APPROACHES TO HANDLING CIRCOVIRUS

John Harding
Department of Large Animal Clinical Sciences
Western College of Veterinary Medicine
University of Saskatchewan
52 Campus Drive, Saskatoon, Saskatchewan S7N 5B4
E-mail: john.harding@usask.ca

INTRODUCTION

Since its discovery and characterization in western Canada in 1995, the significance and dissemination of post-weaning multisystemic wasting syndrome (PMWS) has grown and it has become a serious disease affecting the global swine industry. More recently, there is a heightened interest in PMWS due to the explosive outbreaks in eastern Canada, particularly in Quebec starting in late 2004.

PMWS is caused by Porcine Circovirus type 2 (PCV2), a small single stranded DNA virus. It is the only circovirus known to cause disease in mammals, but other circoviruses cause numerous diseases in birds. By comparison, porcine circovirus type 1 (PCV1) does not cause disease in pigs, and is genetically and antigenically distinct from PCV2. In addition to PMWS of swine, PCV2 contributes to porcine respiratory disease complex (PRDC) and proliferative and necrotizing pneumonia (PNP). It has also been associated with several other conditions including humpy-back swine, porcine dermatitis and nephropathy syndrome (PDNS), congenital tremors (CT-AII), pre-natal myocarditis and reproductive failure. It is important to note that PCV2's involvement in these latter conditions has not been proven.

POST-WEANING MULTISYSTEMIC WASTING SYNDROME (PMWS)

There are several classic clinical signs of PMWS that form the basis of a preliminary clinical diagnosis including enlarged lymph nodes, wasting, dyspnea, diarrhea, pallor, and jaundice (Harding, et al., 1998a & 1998b; Cottrell, et al., 1999; Harms, 1999). While all of these signs will not be noted in a single pig, affected farms will present with the majority, if not all, over a period of time. Confirmation of PMWS requires the presence of clinical signs, hallmark histological lesions and the identification of PCV2 within lesions (Sorden, 2000).

The clinical signs of PMWS are traditionally restricted to the post-weaned aged groups, particularly the late nursery and early grower stages, between 7 and 15 weeks of age (Harding, et al., 1998b). Ironically, the 2004/05 eastern Canadian outbreak appears to affect older hogs, likely due to the dynamics of co-infections and PCV2 viral load specific to the affected farms. Between 1995 and 2005, PMWS in North America most commonly caused low grade and sporadic death loss. On rare occasions particularly in western Canada, severe epidemics resulting in three to four fold increases in post-weaning mortality rates occurred. Persistently high mortality has been noted commonly in some European countries over the

last decade. Interestingly, it is likely that the same is happening in Canada after an 8-year period of quiescence. The reasons for these sudden explosive outbreaks are unknown but current theories include the mutation of PCV2 into a more virulent strain(s), the presence of indigenous or exotic infective cofactors (Agent X), or changes in farm management that “trigger” the onset of disease.

PCV2 STRAINS

The 2004-05 eastern Canadian outbreak is similar in many ways to the PMWS outbreaks in many European Union countries, except that it coincides with the frequent isolation of an apparently novel PCV2 strain, identified as PCV2-321, based on restriction fragment length polymorphism (RFLP) analysis (Carman, et al., 2005). This novel PCV2 strain is over 99% homologous to virulent French and Dutch PCV2 isolates recovered from PMWS cases (Gagnon, unpublished). By comparison, the PCV2 strains recovered in eastern Canada prior to 2005 are only 95-96% homologous to the same French and Dutch PCV2 isolates. Recent Orf2 sequencing of PCV2 strains recovered from diagnostic cases in France, UK, China and Canada in 2004-05 suggests this novel PCV2-321 belongs to a unique cluster of isolates, that is genetically distinct from PCV2 isolates recovered between 1997-99 from western Canada and USA (Hamel, unpublished). Based on the sudden appearance of this new RFLP pattern and the severity of clinical disease and mortality, it is proposed that the 2004-05 PMWS outbreaks in eastern Canada was caused by the dissemination of this novel PCV2 “321” strain which is of increased virulence and possibly imported from France via semen. However, the virulence of this novel PCV2-321 strain has not yet been proven experimentally or by field studies. Furthermore, case-control studies evaluating the molecular characterization of PCV2 strains in France and the Netherlands failed to identify any single mutation or variant strain that was correlated with clinical disease or increased virulence (Boisseson, et al., 2004; Grierson, et al., 2004).

CO-FACTORS AND VIRAL LOAD

While PCV2 infection is clearly a necessity (Allan & Ellis, 2000; Ellis, et al., 2000) and is the only virus consistently recovered from PWMS cases, other co-factors are required for inducing PMWS. These co-factors may include other diseases such as PRRS (Harms, et al., 2001; Pallares, et al., 2002; Allan et al., 2000); mycoplasma, swine influenza (Harms, et al., 2002) and parvovirus (Ellis, et al., 2000; Krakowka, et al., 2000); immune stimulation or vaccination (Krakowka, et al., 2001; Opriessnig, et al., 2003; Kyriakis, et al., 2002); or the absence of good production practices (Rose, et al., 2003; Wallgren, et al., 2005). However, virtually all commercially raised pigs are subclinically infected with low levels of PCV2 (Laroche, et al., 2003; Harding, 2000) yet most remain healthy and do not develop PMWS. By contrast, very high levels of PCV2 are consistently recovered from various tissues and organs of pigs with PMWS (Brunborg, et al., 2004). In fact, the amount of PCV2 in tissues and serum of PMWS pigs (a.k.a. viral load) is correlated with the severity of clinical signs and associated histological lesions in experimentally (Krakowka, et al., 2005; Ladekjaer-Mikkelsen, et al., 2002; Krakowka, et al., 2001) and naturally (Brunborg, et al., 2004;

Segales, et al., 2005) infected pigs. While the viral load in healthy subclinically infected pigs is typically less than 10^6 (per mL serum or 500 ng tissue), the viral load in clinical PMWS pigs generally exceeds 10^7 (Brunborg, et al., 2004). Thus, amplifying viral load is critical for the development of PMWS. In pigs as in all species, antigen presenting cells (APCs) play a fundamental role in the early immune response, by presenting foreign antigens such as viral particles to the effector cells of the immune system. In healthy subclinically infected pigs, PCV2 is contained within APCs in a quiescent state that does not impact APC function or result in cytotoxic effects (McCullough, et al., 2003). Although the immunologic details are unclear, this appears to be a fundamental mechanism of PCV2 induced disease and results in the persistent low level PCV2 infection of lymphoid tissue in healthy pigs. Moreover, co-factors may induce PMWS by attracting PCV2-infected APCs to sites of immune stimulation or infection, where PCV2 is amplified beyond the critical biological “threshold”. This amplification leads to the development of the hallmark lesions of PMWS (granulomatous inflammation, lymphoid depletion) through a number of immune mechanisms, and ultimately to the dissemination of PCV2 to distant systemic sites. Thus, I propose the key to controlling and preventing PMWS in any farm regardless of PMWS status, location, strain or co-factors involved is to reduce and maintain PCV2 viral load below this biologically critical “threshold”.

PCV2 VACCINES

At the time of writing, there are no licensed vaccines in the North American market, although several pharmaceutical companies have products in their pipeline. CFIA has recently granted Merial Canada an import permit for their vaccine (February 2006). Public domain research documenting the efficacy of these experimental vaccines is limited, but the experimental and field research available is promising (Charreyre, et al., 2005; Meng, 2005). The products under development are targeted at both the breeding herd, to enhance the passive immunity of piglets, and feeding herd, to initiate active immunity post-weaning. Both killed and attenuated live vaccines are in the pipe. The use of autogenous vaccines has been suggested, however it is unlikely that autogenous PCV2 vaccines would be effective, and more importantly may not be safe, because PCV2 is difficult to grow in tissue culture, and is very resistant to inactivation.

CONCLUSIONS

Our understanding of the factors impacting the emergence and severity of PMWS on affected farms is not complete; however it is clear that severe disease is associated with high amounts of PCV2 in tissues. Thus, the amplification or upregulation of PCV2 in tissues is a prerequisite to disease expression. Our understanding of the epidemiology and potential triggering factors is improving, particularly the role of adjuvants, vaccines and co-infections. Until vaccines are widely available in Canada, the key to controlling severe PMWS is to implement good production practices and eliminate coinfections to prevent the amplification of viral load. While the emergence of a new PCV2 strain has received considerable attention

in eastern Canada, the industry should be cognizant that the superior virulence of these strains has not been proven.

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PORK PRODUCTION AROUND THE WORLD – CHALLENGES AND OPPORTUNITIES

PORK PRODUCTION IN CANADA - CHALLENGES AND OPPORTUNITIES

Clare Schlegel
Canadian Pork Council
R.R.#1, Tavistock, Ontario N0B 2R0
E-mail: clare@sugarfield.ca

I have access to capital, a comprehensive knowledge of the hog and pork business. Where should my company or I invest, anywhere around the world? Interesting question. This presentation will look at Canada as a possibility and do some analysis from a macro perspective. More detail and the actual presentation will be available at the conference.

In any good business planning process, one needs to not only look at the micro or day-to-day environment, but also the larger context, sometimes called an environmental scan. So, we will go through the challenges and opportunities as I see it for Canada.

The production in Canada is approximately 31 million hogs marketed; 22 million processed in Canada, 3 million exported as market hogs and 6 million exported as weaners/early weaners to the United States. Canadian's consumption of pork has remained stable over many years, resulting in over 50% of the pork produced being exported around the world. Although it is sold to around 100 countries, the largest 5 markets account for over 90%. (Graphs will be shown to demonstrate Canada's positioning)

The pork business has truly become global. Experts predict that the growth in the world trade of pork will continue to increase in the 2 per cent per year range for the foreseeable future as income levels rise in parts of the world and other regions become more dependent on imports (such as Japan and Korea). Part of the global opportunity is to market each cut of pork to the market around the world that has a particular preference for it (ribs to Canada, hams to Mexico, offal to China, etc.)

GEOGRAPHY

Canada is a very large country, spread out on an east/west plane with much of the economic activity within 200 miles of the United States border, particularly processing and further processing. The hog business is spread out across the 3,000 miles coast to coast, concentrating in approximately 3 regions, the Prairies, Quebec and Ontario. Although the farms are more concentrated in Ontario and Quebec, there are huge land bases in the Prairies. Even so, southwestern Ontario is almost as large as Denmark, yet all of Canada produces only a few more pigs than our competitor.

From an environmental perspective, there are limitless opportunities to use the nutrients produced by the livestock for fertilizer. There is generally an abundance of feed grains, and the requirements for value-adding (livestock, processing, etc.) as many communities are

dependent on agriculture. Yet at the same time, particularly in Quebec and Ontario, the industry is geographically close to the huge concentrated North Eastern market in North America.

Canada is closer to many of the major markets than many of its competitors, both to the United States and Asia. Both South America and Europe have significantly farther to travel, thus giving opportunities in the “chilled” markets of Asia, rather than just the “frozen” market. The chilled market is the fresh market in retail.

POPULATION

Although Canada is large, it only has a population of approximately 31 million people. On a pigs per people basis, Canada is one of the lowest in the competitive pork world. As well, on a pig per square mile basis, Canada is also one of the lowest.

This is both a challenge and an opportunity. In the event of a calamity, there is an inadequate consumer basis to support by consumption the local red meat industry. Also securing adequate skilled labour in certain regions is a huge challenge. On the other hand, theoretically society should have less interference with the agricultural business and there are huge opportunities for expansion.

CLIMATE

Canada is a country with four seasons, a temperate climate and geographically diverse. This has a positive impact on breaking disease cycles. The Prairies have a dry climate that is good for livestock production and for disease management. On the other hand, the colder climate requires both more expensive and complex buildings as well as increased expenses for heating. With the extremes of both hot and cold, buildings also have to keep the animals comfortable during the hotter, although generally shorter, periods of the year.

EXPORT DEPENDENCY

Suppliers need to focus on both the domestic and international needs of their customers. They are not always the same and that is both an opportunity and a challenge. The supplier has an opportunity to market each cut around the world where the highest price is found while customers can search the world for the best buy opportunity. Marketing programs, promotion and branding can be difficult because the markets are so different. Greater than 50% of pork is used in the international markets for further processing so there is no opportunity for value-added branding. Rather consistency, continuity of supply and price are critical for these processing markets.

Canada arguably is the most export dependant supplier in the world from the perspective of alternative in the event of significant border issues. Our competitor to the south exports only

approximately 14% of their production, and while Europe is the world's largest exporter; they have also have a population base of well over 200 million people.

Being a major exporter also makes Canada more vulnerable to demand changes around the world. For instance, Canada benefited in the Japanese market both during the BSE crisis and in 1997 when Taiwan, Japan's main importer at the time was eliminated from the market due to FMD. Currently, it could be argued that the Avian Flu problems are causing consumption of chicken to drop, particularly in countries experiencing the disease, thus causing reduced demand in particular for dark meat, making it more difficult for the United States to export, thus increased competition on the protein shelf and reducing prices to the entire protein complex.

CURRENCY

You could argue that currency is only relevant because we are a large exporter. With the strengthening of the Canadian dollar and the weakening of the US dollar, our competitive position is changing. Generally, only approximately 60% (feed) of our variable costs follow the North American currency change while 100% of our income, both pork and hogs vary.

Currency valuation is an indicator though of confidence and health of the Canadian economy. It to a degree indicates health. As we compare ourselves to other emerging competitors, such as Brazil, with relatively poor infrastructure and access to credit, confidence in the economy is an opportunity for Canada.

It could be argued in the long run currency is not the determining factor. However, it is the short-term variability and quick change that creates an enormous challenge for capital-intensive businesses such as hogs and pork.

DISEASE STATUS

Simply put, it is because Canada has been able to stay free of FMD and Hog Cholera that we compete in the elite markets around the world. At this point, Brazil is not in the same markets. Yet the pork business is a tough business.

This highlights the importance of prevention at our borders and a quick response and recovery system, should a foreign animal disease hit. Canada is in the process of developing and implementing a comprehensive system that will be state of the art. However, it takes a long time and significant commitment by both industry and government.

A study done recently for the Canadian Animal Health coalition indicates damage to the Canadian economy of between \$13-\$45 billion dollars by an FMD outbreak in Canada.

INDUSTRY ORGANIZATION & RELATIONSHIP TO GOVERNMENT AND SOCIETY

While this might surprise all of us as one of the macro factors, it is significant. Although agriculture is not always seen as the important driver of the economy in Canada, it is significant as the country is generally resource rich. Agriculture is a base for other value-added activity.

The Canadian pork industry works well together, in an interdependent approach. Governments, both provincial and federal support the industry through activities such as the National Pork Chain Value Roundtable. While the industry believes there is need for significant improvement in focus and priority setting, resulting in quicker responses to opportunities and challenges, this dispersed approach creates greater community support for the industry.

The Canadian industry works particularly well together through jointly owned initiatives such as Canada Pork International. This platform allows for the focused energy in international marketing and the creating of the Canadian platform and brand.

It is through the confidence in systems (for both domestic and international consumers) such as meat inspection (Canadian Food Inspection Agency) and the work of International Trade Canada that allows Canada access to so many international markets. Marketing pork around the world could not happen without this basic infrastructure and support by the government of Canada. It is one of the best in the world.

ACCESS TO CAPITAL/INDUSTRY PARTNERS

One of the most stable economies in the world gives the industry player access to capital, either individually (many farmers) or through the money markets (public companies like some processors). Canada has the skilled and interested businesses and business people to compete. It has a positive climate for long-term investment when the outlook and opportunities are positive. Some of our competitors are struggling in this area. Investment is dependent on stability.

At this point, investment is diverse in the Canadian hog industry. Concentration in certain parts of the supply chain assure world scale operations and targeted professional marketing initiatives worldwide, while opportunities exist for all size of participants.

Concentration within Canada at grocery retail is a reality. For the supply chain to return all interdependent players reasonable returns based on supply and demand over time, the marketplace needs to work efficiently. Some would argue structurally there are problems so I leave it to you to decide.

CHALLENGES AND OPPORTUNITIES TO PORK PRODUCTION AROUND THE WORLD: THE NORTH CAROLINA PERSPECTIVE

**Monte McCaw
Pig Health and Production Group
Population Health and Pathobiology Department
College of Veterinary Medicine, North Carolina State University
4700 Hillsborough St, Raleigh, NC 27606
E-mail: monte_mccaw@ncsu.edu**

ABSTRACT

The points listed below will be discussed more completely during the presentation. It is probably clear that all pork producers in “advanced” cultures are facing similar challenges to their methods, ability, and even right to make a living “raising hogs” or “producing pigmeat”. These pressures are encouraging certain entities to move resources and make investments in “developing” regions of the world where regulations and labor costs are much less restrictive. The picture in these areas is not all roses however, as infrastructure is often poor, governments are unstable, policies also changeable, corruption and bribery add to costs of production, and cultures are not compatible with the “North American” or “European” work ethic or intensive approach to production.

PORK PRODUCTION CHALLENGES - NORTH CAROLINA PERSPECTIVE

C³

Catastrophic Carolina Crud

Catastrophic Canadian Crud

Depends upon where your or your neighbors’ feeder-pigs come from

Circovirus Type 2 Associated Disease Complex / PMWS “Heavy”

PRRSV + Mhyo + SIV + ____ + ____ + ____ +

Swine Influenza Virus antigenic drift and shift

Emergence of H3N2 with human genes

Re-emergence of H1N1 with human and avian genes

NEED FOR AUTOGENOUS SIV VACCINES

Produced from annually collected SIV isolates

Pork Market Access

USA exports ~ 12% of its production to Japan

North Carolina companies highly committed to this market

Antibiotic use and availability for swine diseases, growth promotion

Waste Management Policies

- building moratoriums

- increases in costs of production due to additional treatment steps

Swine Welfare Concerns

- Legislation proposed in high urban population / low swine population states

- PETA, Humane Society of America

Odor

- Human health of workers and neighbors

Use of corn for alcohol fuel production

Use of Soybeans or canola for production of Biodiesel

Cost of fuel for transportation

- Feeder pig / weaned pig exports

- Feedstuffs importation

Foreign Animal Disease outbreaks

- How to cope, mass euthanasia vs. vaccination

Narrowing of Genetic Diversity

- Increased vulnerability to infectious diseases, physiologic problems, etc?

SOME THOUGHTS ON PORK PRODUCTION CHALLENGES AROUND THE WORLD – THE GOOD, THE BAD AND SOME SUGGESTIONS

**John Gadd
International Pig Consultant
Scallow Cottage, Parsonage Lane, Fontmell Magna
Shaftesbury, Dorset SP7 0PB England
E-mail: jngadd@aol.com**

ABSTRACT

A review of what pork producers do well and not-so-well across the world is presented in table form.

Three areas which the author – a widely traveled hog consultant working in 22 countries worldwide – suggests pig farmers should consider in particular are...

1. To travel more so as to see for themselves global ideas which could well be applicable to their own locality and systems of production.
2. To address the problem of labor overload, where ‘tail-chasing’ retards good business management decisions. Suggestions are put forward on how the modern producer/his farm manager can rectify this universal problem.
3. The drag of disease; the author suggests a series of practical, on-farm strategies to arrest and then reduce the worsening situation worldwide, all based on improving the herd’s natural immune defenses.

INTRODUCTION

This paper will not contain the many tables of pig production output, costs, market coverage and economic global details often written about, but is one widely-traveled pig consultant’s experiences and considered opinions on how pig production in the major pig producing industries is progressing (and sadly, retrogressing in some others) as well as some specific suggestions for improvement.

AN OVERVIEW OF WORLD PIG PRODUCTION

We are Still in the Golden Age of Pig Production

So much is happening globally, it is both breathtaking and confusing – and to try to keep pace with it all can be overwhelming (Tables 1 and 2).

Table 1. What is happening worldwide?

Sophisticated pig production industries	Less sophisticated/basic pig industries
<ul style="list-style-type: none"> • Major strides in genetics/AI. • Fewer farms and producers. • Bigger farms through..... • Integration with Agribusinesses. • Profit rather than ultimate performance. • Problems with recruiting and keeping good labor. • Welfare-driven changes. • Pollution awareness. • Wide differences in carcase leanness still extant – quality variable • Disease control is increasingly expensive. • Pay for advice/help/training. • Growing awareness of public opinion. 	<ul style="list-style-type: none"> • Only vague awareness of genetic possibilities and little or no AI. • Wide differences in unit size, but only due to.... • Agribusiness making inroads (financial ‘support’). • Local profit; performance as it comes. • Family or cheap hired labor. • Welfare not a perceived problem. • Minor pollution awareness. • Carcase quality, often poor, is perceived as satisfactory. • Reactive disease control only. • No or little advice etc. sought outside their neighbors. • High awareness of (local) public needs.

Table 2. Worldwide weaknesses.

- Not enough time spent with pigs.
- Not concentrating on the smallest, weakest, slowest pigs.
- Poor at measuring/monitoring.
- Not sufficiently observant. Concentrate! Fresh eyes useful.
- Not clean enough.
- Too much tail chasing.
- Records still poorly used. Too few or no graphics so as to stimulate action.
- Failure to check food and ventilation.
- Not using the veterinarian in a preventive role.
- Buying on price, not on paybacks.
- Not condition scoring / using scanners, etc.
- Outdated housing

A good consultant recoups x5 to x10 of his fees!

Not only does one set of experts, or one University not know it all, but no one pig keeping nation does either. The more I travel among other pig industries, the more obvious this is.

Pig producers don't travel nearly enough to see for themselves what works and what does not on other pig farms/industries.

Every month there are new techniques being adopted, or forced on us by politicians and their bureaucrats, do-gooders and fuss-pots, or alternatively found to be econometrically feasible, (econometrics = the study/application of cost effectiveness).

Practical Developments the Pig Producer Can Use Now

Partial depopulation, later weaning, group housing sows, streaming and segregated pig flow, pipeline feeding, feeding to bolster immune status (Challenge Feeding), Menu Feeding, batch farrowing, cheap eco shelters, outdoor sow production, several methods of turning voidings into a resource, electronic sow feeding.... And so on.

How many of these up-and-running techniques have you looked into?

FUTURE PROMISE

Scientists and researchers are doing great work on genetics and the pig genome, baby pig nutrition, sow nutrition (in my view overdue), viral diseases (after price volatility, probably our greatest threat to profit), auto-sorting and new methods of weighing, organic nutrients and their sources, electronic identification and data logging, computer analysis of performance and progress (in my heretical opinion, this does now need reviewing and improvement), pathogen resistance and antibiotic replacement, odor control, pollution and thinking of voidings as a resource, not as a nuisance.

Great work is being done in all these areas, and more. Trouble is pig farmers in one country understandably follow the lead of their local or national leaders. That's fine, but these same farmers also, through the media, keep an eye on what other pig industries are recommending *but they rarely go and see for themselves*. This is unwise and – dare I say it – may be negligent?

There is no substitute for going and seeing for yourself. I am an international traveler whose on-farm work in the past 5 years alone has taken me to 14 different pig industries, some 116 farms, 7 major commercial firms marketing new ideas or products, 4 Government bodies, 6 Universities doing exciting research and 4 processors revising and enlarging their systems. All since 2000.

This 'go-seeing' has radically influenced my opinions and on-farm advice – as well as providing new or revised material for some 100 articles, papers and 3 books written over the period.

OK so we cannot *all* go see! But what any industry needs to do is send experts you can trust in various sectors – veterinary, housing, management, AI, processing etc. to report back every

2 years with a home economist adding his calculations to the findings. The Danes do this, the British are starting to, and the Japanese do it quietly.

Examples of What “Go-seeing for Yourself” Can Provide

1. **Will the sow stall ban come to Canada?** Maybe, maybe not. Should it do so, you must come and see how we Europeans have set about solving this imposition – because imposition it is – there is little wrong with the sow stall designed and managed properly (but in our case the politicians and the Welfarists won!). We have a *huge* amount of practical experience ready and waiting assessment by you under your conditions. The group housing system we have evolved to replace the stall is (now) brilliant. Performance is *better* than in stalls. Everyone who has made it work is delighted. But it has been a steep (re-)learning curve. (I kept sows in groups 45 years ago.) Before you (have to) jump – come see for yourselves.

2. **We must be paid on (good quality) lean meat, not carcass weight** dead or – perish the thought – live, which latter is a nonsense. Is this happening in Canada yet? No, or not enough? So come and see what the Danes are doing in this area; get totally convinced, and lobby hard for its complete introduction here. Your future livelihood in a competitive world depends on it.

3. **Partial depopulation (PD).** Sure, TD (total depopulation) is best – but what a hassle! What a long time with no income! PD solves 90% of the problem for a practicable cost, with between 75% and 80% of the benefits, done properly. Several veterinary practices in England are experts at the essential protocols. So come over and learn from them, or send your best pig vets over, a better solution, I guess. Here is some interesting data (Table 3) on how PD might rank (under recent British conditions and economics), with other major disease-combative strategies.

Table 3. How does partial depopulation compare with other ‘new’ strategies?

	Cost	Improved Growth	Reduced mortality	Drug use	Approx. payback time
All-in/all-out	Low	1-7%	4.0%	29-45%	Variable*
3 week batch weaning	Low	12-15%	40-45%	30-50%	Long
PD/sow medication	Fair	25-45%	45-65%	55-70%	9-15 months
Full Depop:repop	High	30-40%	65-85%	70-90%	14-26 months

* Depends on how out-of-date is the farm before AIAO, current skill in operating a continuous farrowing regime and the quality of AIAO conversion.

Source: Kingston 2004 (extrapolation)

4. **Lactation feeding.** Always a problem with getting enough nutrients into the sow to sustain these increasingly large litters the geneticists are providing. Ask yourself who in the world have had the most difficulty in getting the farrowed sow to eat enough? *People in hot countries.* At last they have cottoned on – choosing high appetite genes, keeping sows cooler,

using special hot weather diets/ingredients, using water well in combination with controlled ventilation etc. Go see what they are doing and adopt/adapt it to your conditions, e.g. most, maybe all Canadian closed-up farrowing barns I visit are 'too hot and appetite-limiting' and there are ways of getting around this which the Far Easterners have found work for them. Go-see and then use the ideas you can adopt. Sure, the conditions you see out there will be very different, but there are ideas in there which are applicable anywhere.

5. Wet (pipeline) feeding. Sure, in your cold winters a problem – maybe. But we in NW Europe know how to conquer frost/wind-chill down to a certain degree of fridity – and you are the world's experts at cold weather, so your specialists (and you have the best environmental ag. engineers in the world) are on hand to address this problem, thus all it needs is a bit of your expert cold-weather thought given to it.

The advantages of wet feeding for *present* conditions are well documented. The *future* holds far greater promises however, as *only with computerized wet feeding* will you/we be able to design 'variable' feeds to match the growing pigs' immune status; for the feed compounder (or larger farm) to make 300 or more diets from just 3 bulk bins; to use cheaper industrial by-products which don't need to be dried/crystallized (e.g. amino acids, enzymes); to use at-present discarded vegetable matter (brassica tops, banana leaves, herbage), and to develop the *full* phase-feeding enzyme-supplemented, fermentable concept rather the partial, less exploitable dry feed route which is giving variable results under research conditions.

What exciting possibilities, some here now!

So go see the leading wet feeders (latterly mostly German) and get ideas to enthuse your excellent nutritionists (who seem to me only to travel to conferences and not to real leading pig farms?) in this futuristic area. Just travel, guys and carefully examine what's happening at the sharp end of *practical pig production* across the world. And it's a lot! The world's our oyster!

Enough about traveling and go-seeing. Let's have a look at what can be done better (in my opinion) in global pig keeping.

GOOD AND BAD POINTS IN GLOBAL PIG PRODUCTION

All pig farms are different, that is true enough. Yet – strangely – I find pig producers mostly do many 'same' things well, many 'same' things badly. Of course there are climatic differences. A hot, humid locality is very different to a frigid one. Again, hot *dry* (Australia, Spain) is different to hot *wet* (Thailand, Kyushu/Japan) and need different advice.

FIRST THE GOOD NEWS – WHAT YOU DO WELL

Breeding. Great care and effort is put into this area by pig producers and their staff. Sometimes breeders hog-tie themselves in poor mating section design, but their record on

breeding is good, nevertheless. Producers have taken very well to the AI revolution, even if the learning curve has a little way to go yet.

Nursery management on the larger farms is good – improving in leaps and bounds. Segregation strategy is a welcome development.

Use of the veterinarian. Among ‘professional’ pig producers – excellent. The veterinarian is much more of a production partner these days (Table 4). I wish it were so universally; in some countries it is still in the Stone Age!

Table 4. Before-and-after results from using a pig specialist veterinarian to disease-profile 3 farms, with extra vaccination & re-modelling expenses costed in. (US\$ per sow)

Farm	Before			After		
	A	B	C	A	B	C
Estimated cost of disease per year*	284	186	300	80	96	109
Cost of veterinarian	8	3	12	30	27	31
Cost of vaccines & medication†	26	18	30	18	20	21
Cost of remodelling (over 7 years)	–	–	–	27	45	33
Total Disease Costs (US\$)	318	207	342	155	188	194
Difference (Improvement %)	–	–	–	51%	9%	43%

* Disease costs *estimated* from items like the effect of post weaning scour and check to growth on potential performance; respiratory disorders, ileitis, abortions, infectious infertility, *etc.*

† Note that the cost of planned preventive medication was *lower* than for reactive curative medicine.

Source: Clients’ records and one veterinary practice

Dedication. You can be extremely proud of your application. Pig producers and their staff are some of the most dedicated, caring and hardworking individuals when it comes to their skilled and not very salubrious jobs. This is true worldwide. Well done!

A shortish list, maybe, but I confine myself to what is – in my opinion – universal.

NOW TO THE BAD NEWS!

Because my time and space, quite rightly, are limited, I want to deal in fair detail with just two areas where globally, the pig producer *must* improve. These two areas are involved in every farm problem I am asked to solve. *Everyone*, these days (among a variety of other things).

Business Management and ‘Tail Chasing’

I put these two together because the latter has a considerable influence on the former.

Owners and managers are good at the practical hands-on aspects of pork production. In the past they have had to be, so on-farm work comes naturally to them, is enjoyable and satisfying, and includes the instinct of the manager to 'know what is going on'. But this leads to a weakness in our global industry, of the manager/owner's disproportionate involvement in daily practical tasks and not enough measuring, planning and thinking.

Important things in these areas don't get done, or are delayed because – of course – things break, animals get sick, supplies run out, staff go off work, the drain gets blocked, etc. 'Tail chasing' is a major flaw in any pig industry and – if (on-farm) pig production is compared to urban industry (e.g. electronics, retail supermarkets, clothing, etc.) it reveals an enormous, damaging, and – I have to say it – shameful disparity between them and us. In their thinking, in their application of business principles, in their measurement of econometric productivity, and in their acting upon what their monitoring suggests, we have much to learn.

We produce meat, not pigs. Pork production is a business, not a way of life. Profit comes before performance. Bigger is not always the solution – or even best. Spending money in the right place, at the right time, in the right amount is paramount to a decent bottom line.

It may seem a strange thing to say, but I see the need to tail-chase blunting the ability of owners and managers to devote enough time to MANAGING their pig enterprise, on so many of the farms I am asked to help.

So why do pig producers tail-chase?

1. **Not enough staff.** Good staff *is* difficult to get, and with some farms, to keep. A major aspect of a manager's job is to assess the working conditions (generally more important in the workers' eyes than emolument) he provides. You think you are the only business with problems over labor quality and recruitment and retention? Join the club! I've talked to successful non-porcine businesses and it is a major problem for them too. Study how the best of them have solved it – impressively, too. Yes, the same principles given below apply just as much to a pig business as a modern successful retailer, for example: -

Essentials in staff management

- Intelligent; attractive recruiting policy.
- Starting young (school – selling animals, caring, responsibility, computer use, etc).
- Choosing personality, not necessarily qualifications every time.
- Careful induction, with a 'buddy' policy to start with.
- Weekly revision of target-setting and daily conferencing.
- Involvement in graphical records.
- Good working conditions – or if difficult to afford, showing staff an appreciation of the difficulties and what you hope to do about them.
- A career structure.
- Planned and forecasted training to achieve it.

- Having (at least 15%) extra ‘man hours’ planned into the labor load to handle emergencies, or, better less costly, have reserve ‘off-the-team’ people (often retirees) as a back-up.
- Reasonable financial reward. Labor cost is 12-14% of pig production on average (some retail industries 30%) so a 2% hike in this on-cost is not the end of the world and anyway seems magnified in the recipient’s eyes. Built-in as a target-achieved bonus if you like. On every farm I visit with a labor problem *this extra 2% can be found in reducing wastage*. I’ve pointed it out so often when I’ve toured the farm. (Another pair of eyes.) Part of your ‘go-seeing’ policy should be to visit successful non-agricultural businesses and you will see how all the above work for them, and can work for you.

2. Lack of planned delegation. Things go wrong, break down, the unexpected happens. Pig farmers and their more experienced staff are ‘good with their hands’. This encourages them into sorting breakdowns out for themselves, taking up time and physical and mental energy, which is better spent on *managing*, see below. Employ called-in specialists. On the very large farms have your own in-house specialists. Both are cheaper in the end. ‘*Delegation off-farm*’ is a new development for the pig industry, which allows time for better ‘*Decisions on-farm*’.

So how much ‘work’; how much planning, measuring and thinking?

This depends on the size of the farm (Table 5) but my experience with clients suggests that managing a grow-out unit of 500-1000 sows with an adequate labor force (20 man-hours/sow/year or 4-8 men) a manager needs to spend at least 22 - 24 hours per week on non-manual management tasks – between 3½ - 4 hours a day – in order to:

- Look at every pig/pen of pigs once a day (with the veterinarian, once a month).
- Plan and check on pig flow.
- Monitor performance graphically, and think about how to act on it. *You cannot manage what you don’t measure.*
- Staff-briefing, motivation and control.
- Buy well.
- Sell well.
- Plan, fix, monitor, discuss and modify production and fiscal targets.
- Keep yourself up-to-date,
- And.... Be in the right place at the wrong time – and make it look accidental!

Now to the second basic failing world-wide, that of...

IMMUNITY, and Lack of Understanding of the Correct Level of Natural Immunity

The cost of disease from clients’ records. As I’ve said, after price volatility, disease (especially viral disease) is our biggest drag on performance and profit. Compared to what is possible on the best farms my clients’ farm records reveal disease costs us 0.3 on the Food Conversion scale from 7-100 kg (or 28 kg less liveweight sold/tonne feed fed/pig) and 4 fewer slaughter pigs sold/sow and gilt/year (or 26 kg less weaner weight/sow/year at 21-day weaning). This, translated to live slaughter weight at 106 kg is 424 kg of live pig/sow/year

foregone. Both contribute on most farms to a massive one third less gross margin to which has to be added another 5% to 10% extra costs of dealing with disease outbreaks, or the preventive threat of disease.

A 40% loss of profit is quite a realistic disease cost figure across the world. It is a shattering figure! That's what disease probably costs my clients before attention to bolstering immune status, both clinical outbreaks and the under-recognized rumbling, low level, much less apparent, subclinical form.

Table 5. Workload expressed as man hours per sow per year.

	40 farms 120-350 sows		10 farms 825-2040 sows	
BREEDING TO WEANING				
Feeding	4.2		2.1	
Serving	3.5		3.1	
Care and attention	2.5		1.8	
Moving	2.0		1.9	
Cleaning and disinfection	1.8		1.9	
Total	14.0	50%	10.8	57.5%
FINISHING				
Feeding	1.5		1.2	
Moving and weighing	2.0		2.1	
Cleaning and disinfection	1.5		1.1	
Total	8.0	30%	4.4	23.4%
OTHER TASKS				
Repairs and maintenance	2.6		2.1	
Records	1.1		0.8	
Other management	1.0		0.6	
Total	4.7	17%	3.5	18.6%
BUILDING CONSTRUCTION				
	0.9	3%	0.1	0.5%
Total man hours/sow/year	27.6	100%	18.8	100%
Finishing pigs produced/sow/year	19.8		20.1	
Liveweight produced sow/year (kg)	1784		1850	
Labor cost/sow/year (<i>converted to US\$</i>)	US\$252.07		US\$232.18	

Source: Clients' Records

Where does understanding immunity come in? Right at the start of things. The reason why virus disease is on the increase (PRRS, PMWS, Swine 'Flu, Non-specific Infertility to name the four worse problems (in my farm visits recently) is, in my view, because pig farmers all over the world don't understand immunity.

A correct level of protective immunity in a pig herd depends on many things. Worse, it changes continually on the farm according to outside factors, and to the animal's response to challenge. Science can help materially. And does help/is helping. But pig producers can help themselves far more than they do. The most significant effect of this lack of understanding is that pig farmers fail to be convinced that certain precautionary measures are urgently needed. These are management strategy measures and redesigned housing. Also that the level of immune protection differs in breeding stock and in grow-out stock, and a different approach to the acquisition of the correct level of immunity is needed.

CHANGING THE MIND-SET

These measures involve the *willingness to change present production strategies, and... spending the right amount in the right place. The need to spend more money in certain areas affecting immunity is now acute.*

Here is a list of strategies needed to allow a correct natural immune defensive barrier to become established in *any* pig herd.

Breeding

- A longer induction time for bought-in stock, with a distinct challenge and recovery phase.
- Close liaison with a specialist pig veterinarian who monitors the herd's disease profile (see Table 4).
- And thus he/she can advise on what challenge protocols are likely to be most beneficial for the disease picture at the time.
- Not to grow replacement gilts too fast.
- A gilt pool is a valuable asset.
- Generally speaking, get cross-fostering over within 24 hours from birth.
- Colostrum management needs more attention.

Weaning

- Greater attention to cleanliness, especially troughs, in-contact surfaces and signs of looseness.
- Specialist pre-and post-weaning link feeds to reduce dietary stress.
- Carry out a monthly stress audit with your veterinarian.
- Constantly review stocking density (including grow-out pigs once past the post-weaning stage).
- Sanitizing the air (in situ fogging) in cases of respiratory disease.
- Water adequacy post weaning.

General

- All-in/all-out is essential.
- Partial depop. is a very significant defensive measure.
- Correct use of the *latest* anti-viral disinfectants.
- Correct use of the *latest* farm-approved detergents.
- Water sanitation as routine.
- Air sanitation (fogging with pigs present) in cases of respiratory disease.
- Awareness of mycotoxin presence, prevention and control.
- Discipline in vehicular access needs radical stiffening (we learned this from the FM Disease disaster).

Yes, all these protocols cost more money. But not 40% of your profit margin – or even 20%, as we will never live in a perfect world, disease-wise.

I have published – in my two recent textbooks – the costs and paybacks of most of these immune-favorable strategies. The paybacks vary from 2:1 to 12:1. *None* of them have cost more than their proven benefits.

Enough said?

CONCLUSIONS

A very great deal of technical and commercial development in the whole field of cost-effective pig production is in progress across the world despite the wide variety of markets, climate and costs. No one pig production industry or research center knows it all and everybody concerned – especially the pig producer – must travel and see for themselves what other pig farmers and researchers are finding is successful and then think carefully what good or promising ideas may work for them under their own local conditions.

Two weak areas on most pig units today are the lack of time devoted by managers or owners to business management planning, and a poor understanding of management strategies to achieve a correct immune status.

The answers are there to be adopted.

Thank you for listening.

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All the strategies and protocols including clients' performance tables described in this paper can be seen in my two textbooks published in 2004 and 2006.

'Pig Production Problems – A Guide To Their Solutions' (650 pp., 65 checklists).

ISBN 1-897676-34-4

'Pig Production – What the Textbooks Don't Tell You' (265 pp. covering 50 subjects).

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BREAK-OUT SESSIONS

NEW THOUGHTS ON NUTRITION OF NEWLY WEANED PIGS

John Pluske
School of Veterinary and Biomedical Sciences
Murdoch University
Murdoch WA 6150, Australia
E-mail: J.Pluske@murdoch.edu.au

ABSTRACT

Nutrition of weanling pigs remains a key topic of interest in pig production because a good start in the post-weaning period is critical in the subsequent growth, development and survival of pigs through to market. The overriding aim of nutritional programmes is to transition pigs from relatively high-cost diets eaten in smaller quantities to less expensive diets that weaner pigs consume in greater quantities, without detriment to the health and welfare of the animals. Nutritional programmes for weanling pigs are still largely based on the inclusion of antimicrobial compounds such as antibiotics and ZnO, however there is some recognition, even in countries where these compounds are still permitted for use, that sentiment is changing and there is a need to search for other products/strategies to enable pigs to handle the post-weaning period.

INTRODUCTION

The types of feeding programmes for weanling pigs differ around the world, and the nature of these programmes predominately reflect differences in ingredient price/availability (hence diet cost), management considerations (eg. age at weaning), and the general nature of the production system (eg. restrictions on use of antimicrobials in the diet). A plethora of papers, reviews and articles have been written concerning the nutrition of newly weaned pigs, and it is not my intention to reiterate this information. There is no doubt, however, that diet formulation and ingredient selection are critical factors in the successful implementation of nursery feeding programmes, although the age and weight of pigs at weaning are major determinants of performance in the first four weeks following weaning and subsequently through to slaughter (discussed by Dritz, 2004). Similarly, the design of any feeding programme for weaner pigs needs to consider the physiological development (or underdevelopment) of the gastrointestinal tract and interactions with the resident microbiota (Pluske et al., 2004), because the processes of digestion and absorption along with microbial digestion of feed components play key roles in meeting the maintenance requirement of the newly-weaned pig and contributing to growth and, in some circumstances, the gastrointestinal health of the pig. This paper explores some alternative approaches to post-weaning nutrition.

BASIS OF NUTRIENT SPECIFICATIONS FOR WEANER PIGS

Tokach et al. (2003) listed the three major concepts when formulating diets for newly weaned pigs as:

1. Adjusting pigs to the simplest and relatively lowest cost diets as quickly as possible after weaning,
2. Maximizing feed intake to ensure that the pig consumes sufficient energy and nutrients at a time when excess mobilization of body reserves (primarily lipid) can occur, and
3. Formulating the initial diets with highly digestible ingredients that complement the pattern of digestive enzymes, and digestive enzyme development, in the gastrointestinal tract.

Therefore, weanling pig diets have been manipulated predominately to overcome the limitations or immaturity in digestive function so as to maximize the growth of the whole animal. As such, ingredient selection (in addition to cost) to meet these objectives is generally based on nutrient digestibility, amino acid density, lactose concentration, and stimulatory effects on voluntary feed intake from products such as spray-dried animal plasma. The NRC (1998), for example, list the nutrient requirements for pigs of different weights and, as has been described previously in many other papers, nutrient requirements per kg of diet (eg. lysine) and the diet complexity generally decrease with age in accordance with increased feed intake by the pigs. Inherent to changes in diet specifications after weaning is an understanding of the gastrointestinal changes that occur, and this will now be discussed.

FEEDING THE GASTROINTESTINAL TRACT AFTER WEANING

Burrin and Stoll (2003) highlighted the temporal changes in gastrointestinal development and growth after weaning, showing that early-weaned pigs (14 days in this case) have an 'acute phase' lasting about 7 days and a subsequent 'adaptive phase' in which the gastrointestinal tract recovers from the immediate post-weaning insults. Although the duration and magnitude of these phases varies according to factors such as weaning age, environment, genotype and health status, they are generally coincidental with patterns of energy intake and weight gain after weaning (Le Dividich and Seve, 2000), although the variation surrounding these indices can be enormous (Brooks and Tsourgiannis, 2003). Feeding programmes and feed budgets after weaning have evolved to accommodate these two phases and place pigs as soon as possible onto cheaper diets, but the percentage of pigs in a population that fit this generalized pattern is unknown. Indeed, what are the implications for pigs that fall outside this pattern?

In this regard, Burrin and Stoll (2003) remarked that given increases in the understanding of intestinal nutrient utilization of recent times, it is (theoretically perhaps) possible to formulate diets for weanling pigs with the specific goal of optimizing the growth, function and health of the gastrointestinal tract. Their review comprehensively describes some of the most promising candidates they believe could be used in weanling pig diets based upon their known mode(s) of action in the gastrointestinal tract and their utilization in the portal-drained viscera (PDV), the tissues of which include the stomach, pancreas, small and large intestine, and the spleen. In pigs, the PDV tissues contribute approximately 5% of body weight yet account for 20-35% of whole-body protein turnover and energy expenditure (Yen et al., 1997), which reflects their

disproportionately high fractional protein synthesis rates and O₂ consumption. The high rates of metabolism and nutrient utilization in the gut are directly linked to the high rates of proliferation, protein secretion, apoptosis and desquamation of various epithelial and lymphoid cells within the mucosa (Burrin and Stoll, 2003), all of which are a key feature of the post-weaning period.

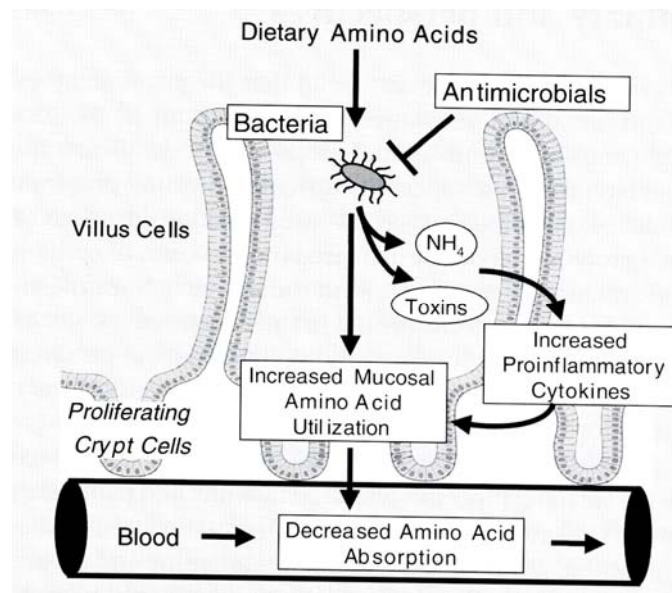
Gut specific nutrients suggested by Burrin and Stoll (2003) include the amino acids glutamine, glutamate and threonine, and the reader is directed towards this review for more extensive information. Glutamine and glutamate are not considered as “essential” amino acids in traditional diet formulations, however there is a large body of evidence in many species, including young pigs, showing some benefits to the addition of these amino acids in the immediate post-weaning period. Arginine, an essential amino acid for neonates but not for growing pigs, was shown by Wu et al. (2004) to decline markedly in plasma during suckling, and supplementation of 0.2 and 0.4% arginine to 7- to 21-day-old artificially-reared pigs increased piglet growth rates by 28 and 66% respectively. Whether there is a conditionally essential requirement for arginine after weaning has not been investigated to my knowledge, however for producers that feed pigs milk liquid diets then attention to arginine levels may be warranted. Obviously major consideration for any of these amino acids of course is the cost of such interventions.

In addition, the influence of post-weaning infections and associated inflammatory responses on aspects of gastrointestinal function warrants mention. Burrin and Stoll (2003) suggested that enteric infection increases intestinal nutrient requirements that in turn limit the availability of dietary nutrients for growth. A schematic illustration of this is shown below (Figure 1). Key questions include how an infection, such as enterotoxigenic *Escherchia coli* infection, alters the pattern of intestinal nutrient utilization, and what are the key nutrients that may either become limiting for intestinal function/body growth and/or assist with gastrointestinal repair. In the case of enterotoxigenic *Escherchia coli* infection for example, which can still be prevalent 10-12 days after weaning, it seems ironic that some pigs in a pen could be offered a lower specification diet just at the time they require a higher specification diet to boost gut repair. Economics and facility management obviously play key roles in addressing this, however from a biological perspective I think this is an interesting question and one worth discussing.

ALTERNATIVES TO ANTIMICROBIALS

Much has been written and spoken, especially in view of the EU ban from 1st January 2006 on the use of prophylactic levels of dietary antibiotic growth promotants, regarding a nutritional ‘magic bullet’ to assist pigs overcome the post-weaning growth check, even in situations where antimicrobials are still permitted for use. Debate and discussions will obviously ensue for some time and more so in parts of the world that face increasing pressure to severely limit/abolish the use of current antimicrobials. Regardless, there is a plethora of products/strategies mentioned when this topic is raised. What I have attempted to do in the following discussion is highlight some ideas that could be considered/reconsidered in this general environment.

Figure 1. Illustration of the relationship between intestinal amino acid metabolism and luminal bacteria (after Burrin and Stoll, 2003).



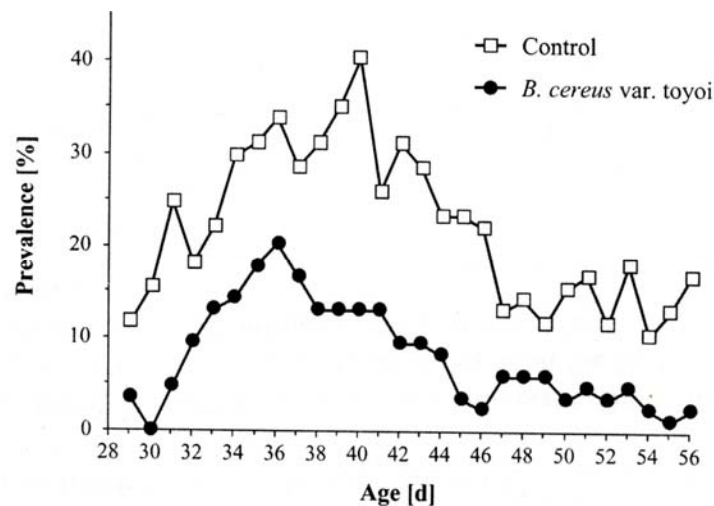
Should I Use Probiotics?

Many different and diverse nutritional strategies are being investigated, and some are being used commercially, to maintain animal performance and intestinal health in the absence of antimicrobial agents. One of these strategies is the use of probiotics, a feed additive containing bacteria that is claimed to improve the intestinal microbial balance (quite vague) and reduce gastrointestinal disturbances in the post-weaning period. Data in the literature purporting the benefits of probiotics for nursery pigs are equivocal, which is no real surprise given the different species and strains that are used and the wide array of weaning and feeding conditions that products work under. Differences in herd health status undoubtedly also contributes to the ambiguity in efficacy seen. Even if a particular probiotic has potential, its usefulness is limited by the newly weaned pig's inability to consume enough bacteria in the immediate post-weaning period, ironically when it is most susceptible to gastrointestinal insults. This lack of a constant, threshold level of probiotic bacteria in the gastrointestinal tract in the population of nursery pigs is a possible reason for the disparity seen in the overall effectiveness of probiotic preparations.

Is there a better way of delivering probiotics? Can we think 'outside the box' with regard to delivering potentially beneficial bacteria instead of relying on a stressed newly-weaned pig to do the job? Work from the UK with fermented liquid feeding (Demeckova et al. 2002) and Germany with *Bacillus cereus* var. *toyoi* (eg. Taras et al. 2005) has suggested that transfer between sows and newborn piglets of bacteria (or a particular species) coupled to an altered microbiota in the feces of the dam exerts a beneficial influence on both pre- and post-weaning development of the young pig. There is also some suggestion of altered milk 'quality' in sows with feeding spores of *B. licheniformis* and *B. subtilis* (Alexopoulos et al., 2004). In the study

by Taras et al. (2005), one group of sows were fed for a period of 17 weeks, from day 24 after mating to day 28 after farrowing, and the piglets from these sows were fed for 6 weeks, from day 15 of lactation to 8 weeks of age. The control group of sows/piglets did not receive the probiotic strain. The *Bacillus cereus* var. *toyoi* was recovered from the feces of sows and piglets throughout the trial, including the period 0-14 days of age before introduction of the starter diet occurred, and there was an improvement in FCR of pigs in the post-weaning period derived from sows fed the probiotic during pregnancy and lactation. Of particular interest in the weaned pigs offered the probiotic was a significant reduction in the incidence of liquid feces (Figure 2) and post-weaning diarrhoea. Diets did not contain any antimicrobial agents, suggesting that this particular probiotic strain reduced the proliferation of enterotoxigenic *Escherichia coli* in the gastrointestinal tract of weaned piglets.

Figure 2. Prevalence of liquid feces (consistency score 4-5) during the total post-weaning period (day 29-56) of piglets in the Control (open boxes) and probiotic (closed circles) group, respectively (after Taras et al., 2005).

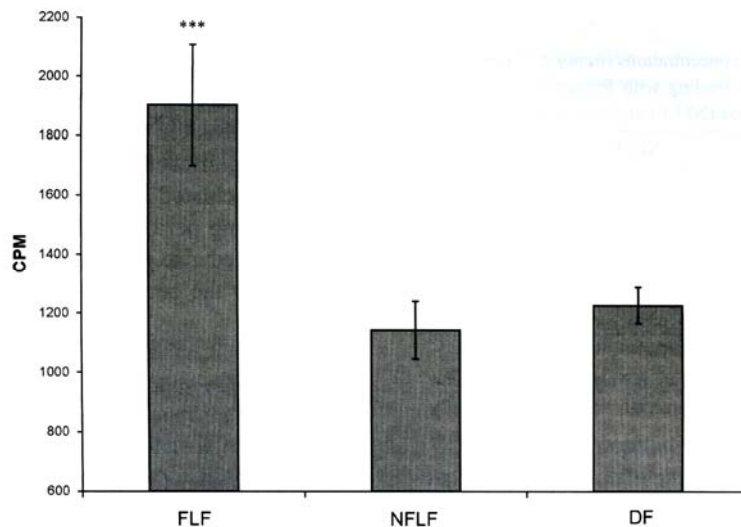


Liquid Feeding of Weanling Pigs

Liquid feeding of growing-finishing pigs is gaining popularity around the world, and in Ontario an estimated 20-30% of pigs are raised using liquid feeding systems (Braun and de Lange, 2004). Liquid feeding can involve partial fermentation of ingredients or diets, and in this instance the production of high concentrations of organic acids (especially lactic acid) and lactic acid bacteria (LAB) are seen as key aspects of the process. Liquid feeding of newly weaned pigs is less common as it is generally viewed as more problematic, but nevertheless there are numerous potential advantages such as the use of cheaper co-products and positive effects on gastrointestinal health and function. Liquid feeding research being conducted at the University of Guelph in newly weaned pigs has focused on comparisons with dry diets, the use of high-moisture corn, and phytase and phosphorus. Data will be presented during the presentation to highlight some of the results of these studies.

Feed may be fermented with wild and/or introduced LAB, and this process has been shown to reduce coliform numbers in both the feed and the gastrointestinal tract. High numbers of LAB in fermented liquid feed (FLF) have been shown to modulate the mucosal immune system (eg. Gill and Rutherford, 2001) that, in a sow, could potentially cause higher levels of colostrum immune factors (better colostrum ‘quality’) and therefore contribute to a more robust piglet at the point of weaning. Demecková et al. (2002) fed sows for approximately 2 weeks before farrowing and 3 weeks after parturition on one of three diets: (i) dry pelleted feed, (ii) non-fermented liquid feed (NFLF), and (iii) FLF. A strain of *Lactobacillus plantarum* was used in the FLF. Demecková et al. (2002) showed that faeces excreted from sows fed FLF had lower numbers of coliforms, and piglets sucking from sows fed FLF excreted faeces higher in LAB and lower in coliforms than their counterparts sucking sows fed dry pellets. Of particular interest in this study though was the enhanced mitogenic capacity of the colostrum derived from sows fed liquid feed, especially the FLF. Colostrum from sows fed FLF and NFLF had a greater mitogenic activity on epithelial cells compared to dry-fed sows, but the colostrum from sows fed FLF only had the greatest effect on mitogenic activity in blood lymphocytes indicating a greater level of lymphocyte proliferation and, by association, possible enhanced immune function (Figure 3).

Figure 3. Mitogenic activity of sow colostrum on blood lymphocytes. Data are expressed as mean counts per minute (CPM). Error bars are standard error of the mean. * $P < 0.001$ (after Demecková et al., 2002).**



Collectively, the data presented in the studies by Taras et al. (2005) and Demecková et al. (2002) suggest an alternative means whereby the overall robustness of the neonatal and weaned pig could be improved, i.e. through the sow. Such an approach could circumvent the issue of low feed intake in the post-weaning period, and hence the low intake of additives/compounds reputed to be beneficial to the newly weaned pig. The data of Demecková et al. (2002) suggest that neonatal defence may be enhanced by manipulating the immune status of farrowing/lactating sows because of the provision of colostrum/milk of greater immunological and nutritional quality. The question remains to be seen, however,

whether any benefits bestowed on sucking piglets can be transferred to the period after weaning.

GASTROINTESTINAL HEALTH, CARBOHYDRATE AND PROTEIN IN DIETS

Data presented nearly 40 years ago by Smith and Halls (1968) showed clearly that providing a source of insoluble dietary fibre in diets for weanling pigs reduced the incidence of enterotoxigenic diarrhea after weaning. The widespread use of antimicrobial agents coupled with advances in feed processing, diet formulation and production systems since this time virtually consigned the word 'fibre' to the sin bin with regard to its usefulness in modulating the gastrointestinal environment of the young pig. The wheel has seemingly turned full circle in some parts of the world because some nutritionists again view dietary fibre as a key weapon in their arsenal to combat post-weaning enteric problems in the absence of antimicrobials.

A large body of information is available on dietary fibre and its effects in pigs, and I will not add to the mound. Rather, I think it is important to discuss dietary fibre, or specifically components of dietary fibre (eg. non-starch polysaccharides and resistant starch), in relation to other dietary components such as crude protein where the gastrointestinal health of the weaned pig is concerned. It appears that an appropriate balance between the 'carbohydrate' content of the diet and the 'protein' content (or undigested protein content) of the diet might play a role in gastrointestinal health and function that in turn impinges upon growth efficiency. Such a concept might not neatly be accommodated with a least-cost diet formulation philosophy, but in situations where, for example, legislation restricts the use of pharmacological levels of minerals and/or antibiotic growth promotants are banned, then such a concept becomes more attractive.

In broilers for example, de Lange (2005) presented data showing a positive linear relationship between FCR and the amount of undigested crude protein in the diet, with the nature of this relationship being different with or without antibiotic growth promotants. The presence of more undigested crude protein in the distal part of the gastrointestinal tract caused deterioration in FCR, with this author suggesting that the end-products of proteolytic fermentation were harmful to the host and stimulated the growth of sulphite-producing bacteria and some LAB that further impaired FCR. More recently in Quebec, Cardinal et al. (2006) examined 34 herds with a weaning age less than 22 days in which 17 herds did not have post-weaning *E. coli* diarrhoea (PWECD) and 17 herds were affected by PWECD. Risk-factor analysis for PWECD showed that the affected herds used higher levels of soybean meal and canola products, and had higher Ca (and Mg) levels and lower Zn and electrolytic balance (EB) levels, than non-affected herds. Cardinal et al. (2006) recommended that to prevent/reduce PWECD, protein of animal origin should be included in the feed for the first 3 weeks post-weaning without high Ca levels.

In somewhat of a contrast, we (Kim et al. 2005) have shown that adding 20 g oat hulls per kg diet to a diet containing cooked white rice as the only cereal (where the starch is 98% apparently digestible at the ileum) and animal protein sources (most likely of varying ileal

digestibility) reduced the incidence of post-weaning diarrhoea and the number of antibiotic treatments. The levels of blood urea nitrogen and concentrations of some biogenic amines were also reduced in pigs given the diet with oat hulls, suggesting that oat hulls changed fermentation characteristics in the hindgut, possibly by altering the balance of the microbiota. Jeaurond and de Lange (2005) reported similar changes in biogenic amine contents using poultry meal and sugar-beet pulp.

It is recognized that the ‘quality’ of animal protein sources varies enormously (eg. Hendriks et al., 2004 showed enormous variation between manufacturing plants in the ‘quality’ of New Zealand meat-and-bone meal), so it is of little surprise that there is disparity between studies. Greater attention to the indigestible component of some protein sources coupled to greater awareness of dietary fibre sources could impact positively on post-weaning pig performance and health, although obviously account needs to be taken of the specific situation in question.

CYTOKINES AND FATTY ACIDS

Interactions between nutrition and immunity are diverse and can have profound implications for pig growth and productivity. Pro-inflammatory cytokines released from macrophages act to both amplify the cellular immune response following immunological challenge and act systemically to change behavior, metabolism and neuroendocrine secretions (Johnson, 1997). The pro-inflammatory cytokines are important mediators of the inflammatory response, and one of the consequences of the weaning process sometimes observed is an elevation in indices of inflammation (King et al., 2003). Transient anorexia in the immediate post-weaning period impairs the integrity of the mucosal epithelium and elevates markers of the inflammatory response (Pie et al., 2004).

Grimble (1998) reviewed the effects of nutrients, predominately antioxidants, proteins and amino acids and fats, influencing the ability of cells to produce cytokines and affecting the ability of target tissues to respond to cytokines. With respect to fats, there is now sufficient evidence both in the literature and commercially advocating the use of some fatty acids in diets modulating both immune and anti-bacterial responses in pigs. In the weaned pig the notion of using specific fatty acids is obviously attractive because they can simply be added to the diet often at little cost and are sometimes as effective as antimicrobial agents. For example, research from Belgium by Dierick et al. (2002) shows strong *in vitro* and *in vivo* anti-bacterial effects of medium-chain fatty acids on the pig proximal small intestine in the absence of traditional antimicrobials.

FEED MANUFACTURING AND QUALITY

Issues including grinding and particle size and pellet ‘quality’, whether or not to use cooked cereals, and pellets versus meal, are always of keen interest to feed manufacturers and producers. Pelleting of diets for young pigs is generally regarded as providing better performance and feed conversion efficiency than meal diets, although attention needs to be paid to the percentage of fines because an increased concentration of fines can bridge feeders

and hence decrease performance (Table 1). Another possible advantage of pellets over meals relates to flow ability of diets. Research using the angle of repose [a measure of the maximum angle (°) at which a pile of ingredients retains its shape] showed greater flow ability in meal diets with granulated specialty protein or coarsely ground lactose sources (Carney et al., 2005).

Table 1. The effect of fines in nursery diets on pig performance (after Stark et al. 1994)^A.

	Minimum fines	300g fines added/kg of diet	Difference, %
Weight gain, g/day	469 ^a	454 ^b	-3
Feed intake, g/day	772	771	0
Feed:gain (g:g)	1.65 ^a	1.70 ^b	+3

^ATrial conducted between 7-21 days after weaning.

^{a,b}Values in a row with a different superscript are significantly different ($P < 0.05$).

A topic that is always of interest is pellet size, yet there is little empirical evidence to make a formed decision. In a factorial study, Edge et al. (2005) offered sucking pigs a creep feed with a diameter of either 5.0 mm or 1.8 mm followed by pellets of either 1.8 mm, 2.4 mm or 5.0 mm diameter after weaning. These authors failed to find any long-lasting effects of pellet diameter on production in the peri-weaning period. Earlier, Traylor et al. (1996) presented data showing that pellets to 12 mm in diameter had no influence on post-weaning performance, as did the provision of a meal-based diet. Nevertheless, details are lacking as to whether manufacture of a smaller pellet influences nutrient (eg. amino acid) availability.

CONCLUSIONS

This paper has attempted to outline some different/alternative philosophies or approaches to nursery pig nutrition. The perennial problem of low feed intake in the immediate post-weaning period, by implication, means that potentially useful compounds are delivered irregularly and/or in suboptimal concentrations to evoke a positive response. Obviously there are many other strategies that could be pursued as 'new thoughts' on weaner pig nutrition, but the cost and overall acceptance by producers of such strategies must be taken into account.

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STRATEGIES FOR FEEDING WEANED PIGS

**Bob Goodband, Joel DeRouchey, Mike Tokach,
Steve Dritz, and Jim Nelssen
Department of Animal Sciences and Industry
Kansas State University
242 Weber Hall, Manhattan, Kansas 66502
E-mail: goodband@ksu.edu**

ABSTRACT

Feeding and nutritional strategies for weaned pigs, regardless of age, should be thoroughly reviewed on a regular basis to ensure success of your nursery nutrition program. Properly designed nutritional programs and feed budgets cannot, by themselves, ensure a successful nursery program. We are beginning to understand that it is not only an issue of *what* to feed the young pig, but equally important is *how* they are fed and managed. A successful nursery feeding program contains several components, but the most important are: A) Start with as heavy and as old a pig as feasible; B) Switch from complex to simple diets as quickly as possible; and C) Provide the proper management to start pigs promptly on feed and water and continually adjust feeders to optimize feed efficiency.

STRATEGIES FOR FEEDING WEANED PIGS

Start with as Heavy and as Old as Possible Pig

Recent Kansas State University research (Main et al., 2004; 2005) has shown that increasing weaning age through 21 days linearly increases growth rate and reduces mortality from weaning to market. In these studies, wean-to-finish growth performance and productivity (as measured by ADG, mortality, off-test weight per day of age, and weight sold per pig weaned) improved as weaning age increased from 12 to 21 days of age (Table 1). Linear improvements in growth and mortality rate largely occurred in the initial 42 d post-weaning period, with some ongoing growth improvements in finishing performance. Financial performance improved linearly as weaning age increased up to 21.5 days. Data were then modeled to determine the linear rates of improvement observed as weaning age increased from 15 to 21.5 days (Table 2). Each day increase in weaning age increased initial weight (taken prior to weaning) 256 ± 4 g and weight sold to slaughter 1.80 ± 0.15 kg per pig weaned. In the financial analysis, income over cost increased $\$0.94 \pm 0.07$ per wean age day in the limited finishing space scenario and $\$0.53 \pm 0.06$ per wean age day in the non-limited space scenario. These studies suggest increasing weaning age up to 21.5 days can be an effective production strategy to improve wean-to-finish growth performance in a multi-site production system.

Switch from Complex to Simple Diets as Quickly as Possible

The keys in diet formulation are remembering that: 1) feed intake drives growth performance; 2) complex diets with specialty ingredients increase feed intake during the first few weeks after weaning; 3) diet complexity must be reduced rapidly as the impact on feed intake declines. Common mistakes in nursery diet formulation include: 1) selecting ingredients that are highly digestible, but not highly palatable; 2) using whey or protein sources that are not high quality; 3) using high fiber ingredients in nursery diets in an attempt to help gut health; and 4) feeding complex, expensive diets too long.

Table 1. Influence of weaning age on wean-to-finish performance^a.

Item	Weaning age				SE	Probability (P<)	
	12	15	18	21		Linear	Quadratic
Allotment weight, kg ^b	3.42	4.26	4.89	5.75	0.05	0.001	0.68
Off-test weight, kg	103.9	109.1	112.1	117.3	0.81	0.001	0.94
ADG, g	580	616	637	687	8	0.001	0.36
Mortality, %	9.39	7.88	6.80	3.68	0.95	0.001	0.39
ADG per d post-weaning, g	643	671	686	714	5	0.001	0.96
Weight sold per pig weaned, kg	94.1	100.5	104.4	113.1	1.30	0.001	0.35

^aAdapted from Main et al. (2004). A total of 2272 pigs with 34 or 36 pigs per pen (50% barrows, 50% gilts), and 16 replications (pens) per treatment, or a total of 64 pens on test in the nursery and 1,920 pigs with 20 pigs per pen and 24 replications (pens) per treatment, or a total of 96 pens on test in the finisher.

^bAllotment weights were taken on all pigs 3 d prior to weaning.

Table 2. Modeling the linear rate of change observed as wean age increased from 12 to 21.5 days^a.

Item	Rate of linear change per day increase in wean age	
	Change per day	SE
Allotment weight, kg ^b	0.257	0.003
d 42 post-weaning, kg	0.93	0.017
Off-test weight, kg	1.35	0.08
Wean-to-finish ADG, g	9.9	0.74
Wean-to-finish mortality, %	-0.47	0.09
Weight sold per pig weaned, kg	1.80	0.12

^aAdapted from Main et al. (2005). Modeling the linear rate of change (magnitude of change per d increase in weaning age) in wean-to-finish performance observed as weaning age increased from 12 to 21.5 days (trial 1 = 96 finishing pens with 20 pigs per pen, and trial 2 = 120 finishing pens with 25 pigs per pen).

^bAllotment weights were taken on all pigs 3 d prior to weaning.

Feed budgeting: weaning to 7 kg. The goal of the nutritional program remains the same regardless of the number of diet phases used. That goal is to transition pigs to a low cost, grain-soybean meal-based diet as quickly as possible after weaning without sacrificing growth performance. In most cases, pigs achieve this goal without higher-cost products such as whey or fish meal after 11 to 12 kg body weight. A four-phase feeding approach replaced the traditional, three-phase system in the nursery phase when younger weaning ages were implemented in multi-site pig production. With later weaning, many considered reevaluating feed budgets and starter diet complexity. However recent research suggests that even with older, heavier pigs, the traditional 4-phase program offers the greatest margin over feed costs (Tables 3 and 4).

Table 3. Effect of pelleted vs. meal diets and modified feed budget on growth performance of weanling pigs in a commercial environment^a.

Diet Form:	Pellet 1	Pellet 2	Meal					
Plasma, %:	6.7/2.5%	6.7/2.5%	2.5%		4%			
SEW, kg/pig:	.45	.23	--	--	--	--		
Transition, kg/pig:	1.36	.45	.91	1.81	.91	1.81	SE	P <
Day of diet switch ^b								
Trans to Phase 2	11.2	6.2	7.0	11.2	8.0	11.0	0.1	0.01
Phase 2 to 3	22.3	20.0	20.5	22.7	21.2	22.5	0.3	0.01
d 0 to 28								
Final wt, kg	14.3	14.0	13.7	13.9	13.7	13.9	0.09	0.01
ADG, g	299	290	277	281	277	281	4.54	0.01
ADFI, g	404	404	399	399	395	4.4	4.54	0.65
F:G	1.34	1.39	1.45	1.41	1.43	1.43	0.01	0.01
Removals, %	3.0%	2.1%	4.8%	5.1%	3.9%	4.5%	1.1%	0.27
Feed, \$/kg gain ^b	\$0.34	\$0.37	\$0.35	\$0.36	\$0.35	\$0.38	\$0.004	0.01
Margin over feed ^c	\$5.53	\$5.06	\$5.02	\$4.99	\$4.99	\$4.87	\$0.10	0.01

^aGroesbeck et al. (2005). Each value is the mean of 6 feeders (2 pens/feeder and 28 pigs/pen). All pigs were fed the 5.4 kg/pig of the phase 2 after the indicated amount of SEW and Transition had been fed.

^bDiet costs used were \$596.50, \$442.70, \$360.61, \$401.95, \$241.12, and \$161.64/ton for SEW, Pelleted Transition, 2.5% Plasma Transition, 4% Plasma Transition, Phase 2, and Phase 3, respectively.

^cMargin over feed was calculated as d 0 to 21 gain × \$.99/kg minus feed cost for d 0 to 21.

Table 4. Recommended feed budgets for older weaning ages and weights.

Diet,	Weaning Weight, kg/pig			
kg/pig	4.5	5.5	6.5	7.5
SEW	0.9	0.5	0.25	0.25
Transition	2.2	1.4	0.5	-
Phase 2	6 to 7	6 to 7	6 to 7	6 to 7

7 to 11 kg. This diet is typically a grain-soybean meal-based diet with 7 to 10% of a high-quality source of lactose and a small amount of a specialty protein source, such as spray-dried blood meal or high-quality fish meal. Other specialty protein sources may be used, depending on economic considerations or location. Many producers make this diet in meal form on their farm.

For producers in the U.S., growth-promoting antibiotics and zinc oxide are typically used in this diet. Research indicates that 2,000 ppm zinc is the optimal inclusion level (Smith et al., 1999). When zinc oxide is used for growth promotion, high levels of copper sulfate do not provide any additional growth response (Smith et al., 1997). Typically, 7 kg of feed is budgeted for pigs during this phase.

11 to 23 kg. This diet should resemble a grow-finish diet, which in most cases will be a simple grain-soybean meal diet without any specialty protein products or lactose sources. The digestive capacity of the pig by this weight is such that these ingredients are unwarranted; including them will increase feed cost/pig.

This diet is the lowest-cost diet in the nursery program. However, since consumption of this diet is the greatest during the nursery phase, it usually accounts for more than half of the total feed cost from weaning to 23 kg. Typically, 20 to 23 kg of feed is budgeted for pigs during this phase.

Because long-term feeding of high levels of zinc oxide has not been shown to be beneficial, growth-promotion levels of zinc should not be used in this ration. Copper sulfate at 125 or 250 ppm of complete diet and antibiotics can serve as effective growth promoters in this phase.

It is critical to practice strict discipline when using a feed budget to prevent overfeeding of the more expensive nursery diets past the desired weight range. Often, this is the major cause of high feed costs in the nursery. Listed in appendix 1 of this paper are some suggested specifications for SEW and Transition diets as well as options for phase 2 and 3 diets.

Ingredients and Ingredient Quality

The decision to add fat to the diet will depend on the ability of the producer or feed company to economically purchase it. Fat is routinely added to SEW and Transition diets because these diets are typically pelleted. Added fat will serve to lubricate the pellet die and help make a high quality pellet. By increasing added fat in diets for pigs greater than 7 kg, pigs will often respond with improvements in average daily gain and feed efficiency. From 3% to 5% added fat is a common recommendation. Weanling pigs appear to be most affected by poor quality fat sources. Therefore, choice white grease or plant sources such as soybean oil are recommended. Fat sources such as beef tallow, poultry fat and restaurant fats should be avoided in nursery pig diets.

The use of high-quality protein sources, such as spray-dried animal plasma and blood meal, fishmeal and lactose sources, purchased from a reputable source, can assure producers that ingredient quality is not a limiting nutritional factor in nursery pig diets. Producers who decide to manufacture on-farm nursery diets in meal form may choose to utilize granular

specialty protein and lactose sources that have better flow ability properties. Products with poor flow characteristics can lead to problems with bins and feeders bridging, thus limiting feed intake.

PROVIDE PROPER NURSERY PIG MANAGEMENT

The best nursery diets cannot overcome poor management. When pigs enter the nursery, they should have continual access to feed and water. Techniques, such as dripping water from cups or nipples, or gruel feeding, should be used during the first few days after weaning to encourage feed and water consumption. After pigs have started on feed, feeders need to be adjusted frequently to minimize wastage to achieve excellent feed efficiency. The most common feed management problems in nurseries are: 1) not making feed and water easy for the pigs to find after weaning; 2) treating starve-out pigs with antibiotic injections instead of helping them find feed and water; and 3) having too much feed in feed pans leading to spoiled and wasted feed.

Water Intake

Newly weaned pigs dehydrate rapidly and must have readily available drinking water. Whether you are providing water through nipple or bowl drinkers, proper positioning and sanitation of watering devices are essential elements of proper pig hydration. Either cup or nipple-type drinkers are suitable for weanling pigs. However it is important to set them to trickle water for the first 12 to 24 hours once pigs are placed in the nursery so the pigs can find them. Secondly, it is a common mistake to set the drinker too high for the pig to reach. Nipple drinkers should be adjusted so the nipple is shoulder height of the pig.

Also, to maximize feed intake, pigs must be provided unrestricted access to feed. Producers often limit-feed pigs to reduce postweaning diarrhea. However, recent research indicates that limit feeding current highly digestible nursery diets actually increases the risk for diarrhea (Madec et al., 2000). Limit feeding is a frequent cause of reduced nursery exit weights.

A number of management lapses may also result in limited feed intake. These include failure to investigate all potential contributing areas like improper air temperature or ventilation, poor sanitation or undetected disease challenges.

Social interaction between the piglets while eating is critical to develop feeding behavior. Feeders with solid partitions prevent this feeding interaction because piglets cannot see each other while eating. A properly designed feeder without solid partitions encourages proper social interaction and maximum feed intake, while preventing the small pigs from laying and defecating in the feeders.

Feeding mats are also useful to facilitate social interaction during feeding for the first few days after weaning. While useful to facilitate social interaction, mats can lead to higher levels of feed wastage and disease risk from improper sanitation if kept in the nursery pen too long.

Feeder Adjustment

Proper and frequent feeder adjustments are the keys to excellent feed efficiency and low feed cost in the nursery. Feeder adjustment must start with the first feed placed in the feeder. Regardless of whether the first diet comes in bags or bulk, the feed gate in all feeders should be closed before placement of the first pellets. The feed gate then should be opened so that a small amount of feed is visible in the feed pan. Placing pelleted feed into an empty feeder with the agitation gate open will result in large amounts of feed filling the trough, leading to feed wastage and difficulty in achieving the proper feeder adjustment.

Although adequate amounts of feed must be present in the feeder at all times after weaning, too much feed in the pan of the feeder can also decrease growth rate. In an attempt to stimulate feeding behavior, some producers place large amounts of the first diet in the feeding pan. Although the intention is positive, the outcome is negative. Energy deficiency can result from pigs “sorting” the diet and producing a buildup of fine feed particles (“fines”) in the feeding pan that pigs can find less palatable. These fines then lodge in the feed agitator mechanism, making it difficult for new feed to flow from the feeder.

To correct this problem, manage the amount of feed flow in the pan to stimulate the development of feeding behavior. Approximately 50% of the feeding pan should be visible in the first few days after weaning. As the pigs become more accustomed to the location of the feed and adjust their feeding behavior, the amount of the feed in the feeding pan should be decreased rapidly to less than 25% coverage. Also, feed agitators need to be tested and adjusted frequently to ensure that the buildup of fines does not prevent them from working freely.

Identifying Starve-outs

In our experience, weaning an older pig will reduce but not eliminate starve-out pigs. It’s essential to have a dedicated workforce that can identify the signs of a starve-out pig, and then gently teach the pig where and how to eat with either mat or individual feeding system.

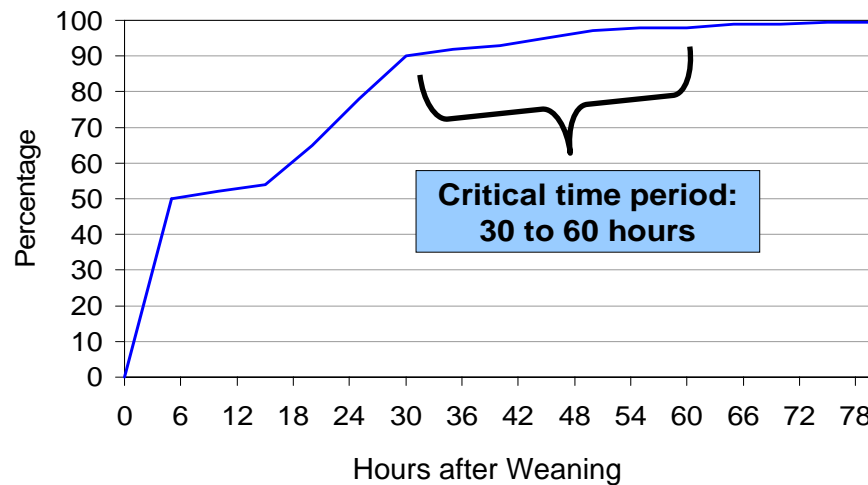
Some pigs simply do not start eating readily after weaning – regardless of age. Producers who have the ability to teach these starve-out pigs to eat, rather than treating them with an antibiotic, will save more pigs.

The main signs to help identify starve-out pigs include:

- Mental status – depressed;
- Body condition – thin;
- Abdominal shape – gaunt;
- Skin – fuzzy;
- Appetite – huddled with no activity at the feeder, and
- Signs of dehydration – sunken eyes.

It would appear that the most critical time to identify and assist pigs who do not begin to eat is approximately 30 hours after weaning (Figure 1).

Figure 1. Percentage of pigs that have eaten by hours after weaning (adapted from Bruininx et al., 2001).



Pen Space

One of the largest advantages with later weaning is the improvement in pig growth rate, both in the nursery and finishing stages. For every day of increased weaning age up to 21 days of age, producers should expect that pigs will be over 1.4 kg heavier from weaning until marketing on a fixed day system, or marketed 1.7 days faster. However, nursery pen space must be managed carefully. With a higher initial weight and the expected increase in growth rate, space allotments/pig need to be adjusted accordingly. Pig space will need to be increased if pigs remain in nursery pens for the same number of days before being moved to finishing barns. In wean-to-finish facilities, this is not a concern unless producers are double stocking during the nursery phase of growth.

Sorting Pigs by Weight

The sorting and grouping of pigs by body weight is a common management technique believed to minimize variation. Thus, pigs commonly are grouped at weaning in light, medium, and heavy weight pens. However a recent study (Tokach et al., 2003) where pigs were sorted into groups of light, medium and heavy weight groups, or left unsorted, showed that sorting pigs by weight had no advantage on final weight or the percentage of cull and removed pigs (Figures 2 and 3). In fact, it could be argued that sorting pigs by weight in the nursery could even have some negative implications on growth rate. It has also been demonstrated that in finishing pigs, sorting weight has no advantage on either growth rate or market weight variation.

Figure 2. Effects of sorting pigs into the nursery on final weight (adapted from Tokach et al., 2003).

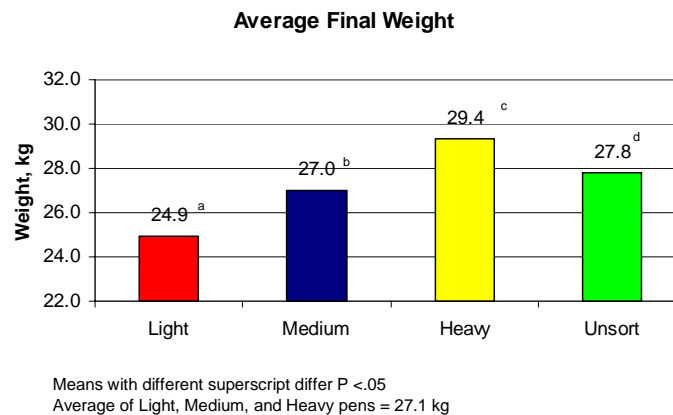
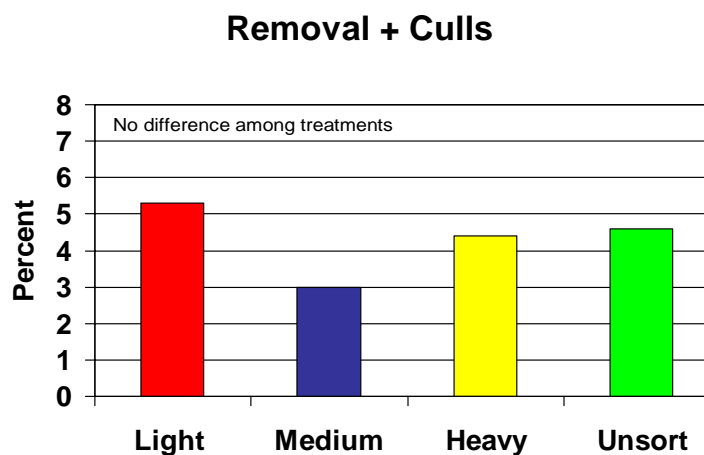


Figure 3. Effects of sorting pigs into the nursery on percentage of cull and removed pigs (adapted from Tokach et al., 2003).



RECOMMENDATIONS AND PROCEDURES FOR FILLING ROOMS (OR BARNs)

When moving weanling pigs into a nursery room:

1. Sort out the 10 to 15% of the very lightest pigs. These pigs will include any lame pigs, runt pigs, ruptures or any other pigs that will require specialized attention and care. These pigs are typically put into “hospital” or “disadvantaged pig” pens. They will be allowed a more generous (increased amounts) of the initial starter diets.
2. The remaining 85 to 90% of the pigs get randomly placed in pens without any special attention to initial weight. These pigs will be fed the standard amounts of feed according to the feed budget.

If you will be:

1. Feeding the entire room or each individual pen a different feed budget;
2. Managing individual pens of pigs differently, i.e., vaccinations, environmental modifications or any other management procedure that will be weight specific, then it is probably worth the added labor to sort pigs by weight.

Creep Feeding

The effectiveness of creep feeding is an area open to considerable debate now that weaning age has increased. During the past decade, providing creep feed to early-weaned pigs typically has not been advocated when weaning age is less than 21 days. However, with older-weaned pigs and longer lactation lengths, if properly managed, this practice may help alleviate pressure on the sow while helping pigs get off to a more rapid start in the nursery. This is an area that needs more research before a definitive recommendation can be made.

If producers do decide to offer creep feed to pigs supplying a high-quality starter diet equivalent to a SEW diet for earlier-weaned pigs is recommended. Creep feed must be kept fresh and in feeders or troughs that prevent excess wastage. Even though only small amounts are actually fed, the cost of creep feeding, if not managed properly, will increase the cost/weaned pig beyond the returned benefit.

CONCLUSIONS

The basic concepts and management practices for feeding older-weaned pigs are not different than those for younger weaning ages. Intense management of newly weaned pigs to get them started on feed as soon as possible is critical to the success of the nutritional program.

Ultimately, producers who have high nursery feed intake, follow strict nursery feed budgets, use high-quality ingredients and maximize sow lactation feed intake will also maximize profitability.

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APPENDIX 1

Complete Starter Diet Specification (SEW) – Page 1 of 2

Name:

Product name: SEW Diet

Address:

Quantity, kg

Package size, kg

Phone: _____ Fax:

Use: To be fed to pigs weighing less than 5.4 kg
as a complete diet.

Date:

Price: FOB or \$/ton Delivered

DATE NEEDED:

Ingredients	Units	Guaranteed Potency In Complete Diet	Sources
Spray-dried whey	%	25.0	Edible grade from Land O'Lakes or equivalent
Lactose	%	5.0	Edible grade
Spray-dried animal plasma	%	6.7	American Proteins, DuCoa, Merricks, or North Central Processors
Spray-dried blood meal or cells	%	1.65	American proteins, California Spray Dry, or Merricks
Menhaden fish meal	%	6.0	Special Select Menhaden from Omega Proteins
Corn Minimum Maximum	%	33.0	
	%	36.0	
Soybean meal, 46.5% protein	%	12.5	
Fat	%	6.0	Soybean oil or choice white grease
Monocalcium phosphate (21% P)	%	0.50	
Limestone (38% Calcium)	%	0.40	
L-lysine HCl	%	0.15	
DL-methionine	%	0.15	
Salt	%	0.25	
Zinc oxide	%	0.375	
Acidifier	%	0.20	Kemgest, Syneracid, Digest acid or ADM Select Acid
Vitamins	Units	Guaranteed Potency Added per Ton of Complete Feed	Sources
Vitamin A	IU	10,000,000	Vitamin A acetate (retinyl acetate)
Vitamin D	IU	1,500,000	Vitamin D ₃ (cholecalciferol)
Vitamin E	IU	40,000	d or dl- -tocophorol acetate
Vitamin K (menadione)	mg	4,000	MPB (Menadione dimethylpyrimidinol bisulfite) or MNB
Vitamin B ₁₂	mg	35	Cyanocobalamin
Niacin	mg	45,000	Niacinamide, Nicotinic acid
Pantothenic acid	mg	25,000	d-calcium pantothenate
Riboflavin	mg	7,500	Crystalline riboflavin
Choline	mg	150,000	Choline chloride
Pyridoxine	mg	2,000	Pyridoxine hydrochloride

Complete Starter Diet Specification (SEW) – Page 2 of 2

Minerals	Units	Guaranteed Potency Added per Ton of Complete Feed	Sources
Copper	g	15	Copper sulfate
Iodine	mg	270	Ca iodate, Ethylenediamine dihydriodide (EDDI)
Iron	g	150	Ferrous sulfate, Ferrous carbonate
Manganese	g	36	Manganese sulfate, manganese oxide
Selenium	mg	270	Sodium selenite
Zinc	g	2,700	Zinc oxide (MUST BE ZINC OXIDE)
MEDICATION (AS DECIDED BY THE PRODUCER)	Units	Guaranteed Potency Added per Ton of Complete Feed	Sources (Decided by the producer)

The following points must be followed unless approval for changes have been made:

- Must be pelleted in 1/8 or 3/32" pellets.
- Guaranteed to stay free-flowing, lump free, and non-dusty.
- When bagged, all bags must be labeled with tags. Tags should include date of manufacture, lot number, guaranteed analysis, inclusion rate, and proposed use of the product.
- Formulate using the guaranteed analysis from the supplier for the nutrient. We can request label copies of your ingredients and copies of your mixing records to show quantities of ingredients per batch.
- Permission must be obtained before using an alternative source for any ingredient.

Complete Starter Diet Specification (Transition) – Page 1 of 2

Name:

Product name: Transition Diet

Address:

Quantity, kg

Package size, kg

Phone: _____ Fax:

Use: To be fed to pigs weighing between 4.5 and 6.8 kg as a complete diet.

Date:

DATE NEEDED:

Price: FOB or Delivered

Ingredients	Units	Guaranteed Potency In Complete Diet	Sources
Spray-dried whey	%	25.0	Edible grade from Land O'Lakes or equivalent
Spray-dried animal plasma	%	2.5	American Proteins, DuCoa, Merricks, North Central Processors
Spray-dried blood meal or cells	%	2.5	American proteins, California Spray Dry or Merricks
Menhaden fish meal	%	2.5	Special Select Menhaden from Omega Proteins
Corn Minimum	%	36.0	
Maximum	%	39.0	
Soybean meal, 46.5% protein	%	20.0	
Fat	%	5.0	Soybean oil or choice white grease
Monocalcium phosphate (21% P)	%	1.10	
Limestone (38% Calcium)	%	0.60	
L-lysine HCl	%	0.15	
DL-methionine	%	0.15	
Salt	%	0.30	
Zinc oxide	%	0.375	
Acidifier	%	0.20	Kemgest, Syneracid, Digest acid, or ADM Select Acid
Vitamins	Units	Guaranteed Potency Added per Ton of Complete Feed	Sources
Vitamin A	IU	10,000,000	Vitamin A acetate (retinyl acetate)
Vitamin D	IU	1,500,000	Vitamin D ₃ (cholecalciferol)
Vitamin E	IU	40,000	d or dl- -tocophorol acetate
Vitamin K (menadione)	mg	4,000	MPB (Menadione dimethylpyrimidinol bisulfite) or MNB
Vitamin B ₁₂	mg	35	Cyanocobalamin
Niacin	mg	45,000	Niacinamide, Nicotinic acid
Pantothenic acid	mg	25,000	d-calcium pantothenate
Riboflavin	mg	7,500	Crystalline riboflavin
Choline	mg	150,000	Choline chloride
Pyridoxine	mg	2,000	Pyridoxine hydrochloride

Complete Starter Diet Specification (Transition) – Page 2 of 2

Minerals	Units	Guaranteed Potency Added per Ton of Complete Feed	Sources
Copper	g	15	Copper sulfate
Iodine	mg	270	Ca iodate, Ethylenediamine dihydriodide (EDDI)
Iron	g	150	Ferrous sulfate, Ferrous carbonate
Manganese	g	36	Manganese sulfate, manganese oxide
Selenium	mg	270	Sodium selenite
Zinc	g	2,700	Zinc oxide (MUST BE ZINC OXIDE)
Medication (As decided by the producer)	Units	Guaranteed Potency Added per Ton of Complete Feed	Sources (Decided by the producer)

- a) The following points must be followed unless approval for changes have been made:
- b) Must be pelleted in 1/8, 3/32, or 5/32” pellets.
- c) Guaranteed to stay free-flowing, lump free, and non-dusty.
- d) When bagged, all bags must be labeled with tags. Tags should include date of manufacture, lot number, guaranteed analysis, inclusion rate, and proposed use of the product.
- e) Formulate using the guaranteed analysis from the supplier for the nutrient. We can request label copies of your ingredients and copies of your mixing records to show quantities of ingredients per batch.
- f) Permission must be obtained before using an alternative source for any ingredient.

Ingredient, %	Phase 2 options (15 to 25 lb)			Phase 3 25 to 50 lb
	Blood meal	Fish meal	Deproteinized whey	
Corn	51.70	52.30	52.10	58.30
Soybean meal, 46.5% CP	28.35	26.65	26.45	34.80
Select menhaden fish meal		4.50	6.00	
Spray-dried blood cells	2.50			
Spray dried whey	10.00	10.00		
Deproteinized whey			9.00	
Choice white grease	3.00	3.00	3.00	3.00
Monocalcium P, 21% P	1.10	0.55	0.45	1.15
Limestone	0.85	0.50	0.45	0.95
Salt	0.30	0.30	0.30	0.35
Zinc oxide	0.25	0.25	0.25	0.00
Vitamin premix with phytase	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15
Lysine HCl	0.25	0.30	0.30	0.30
DL-Methionine	0.18	0.15	0.15	0.13
L-Threonine	0.13	0.13	0.14	0.13
Antibiotic 1	1.00	1.00	1.00	0.50
TOTAL	100.00	100.00	100.00	100.00
TID Lysine, %	1.35	1.35	1.35	1.30
Total lysine, %	1.49	1.48	1.48	1.44
TID Lysine:ME ratio, g/Mcal	3.99	3.94	3.92	3.79
TID Isoleucine:lysine ratio, %	54%	59%	59%	62%
TID Leucine:lysine ratio, %	132%	121%	119%	128%
TID Methionine:lysine ratio, %	34%	36%	36%	33%
TID Met+Cys:lysine ratio, %	56%	58%	58%	57%
TID Threonine:lysine ratio, %	62%	62%	62%	63%
TID Tryptophan:lysine ratio, %	18%	17%	17%	18%
TID Valine:lysine ratio, %	73%	65%	65%	69%
ME, kcal/kg	3,382	3,423	3,439	3,432
Protein, %	21.5	21.3	21.4	21.6
Calcium, %	0.71	0.71	0.72	0.71
Phosphorus, %	0.65	0.65	0.66	0.64
Available phosphorus, %	0.37	0.38	0.38	0.32
Available phosphorus equiv, %	0.47	0.48	0.48	0.42
Avail P:calorie ratio g/mcal	1.40	1.39	1.41	1.22

Vitamin Premix Specification Form with Phytase

Name: _____ Product name: Vitamin Premix with Phytase

Address: _____ Quantity, lb _____ Package size, lb _____

Phone: _____ Use level, lb/ton Sow diets: 2.27 kg

Fax: _____ Nursery diets: 2.27 kg

Date: _____ Grower diets: 1.36 kg

Date Needed: _____ Finisher diets: 0.68 to 1.13 kg

Price desired (circle one) \$/lb FOB _____

Delivered \$/lb _____

Nutrient	Units	Guaranteed Potency per lb of premix	Sources
Vitamin A	IU	2,000,000	Vitamin A acetate (retinyl acetate)
Vitamin D	IU	300,000	Vitamin D ₃ (cholecalciferol)
Vitamin E	IU	8,000	dl- α -tocophorol acetate or d- α -tocophorol acetate
Vitamin K (menadione)	mg	800	MPB (Menadione dimethylpyrimidinol bisulfite) or MNB
Vitamin B ₁₂	mg	7	Cyanocobalamin
Niacin	mg	9,000	Niacinamide, Nicotinic acid
Pantothenic acid	mg	5,000	d-calcium pantothenate
Riboflavin	mg	1,500	Crystalline riboflavin
Phytase	FTU	90,700	Natuphos
Carrier			50:50 mixture of rice hulls and limestone
Oil	%		Mineral or vegetable

The following points must be followed unless approval for changes have been made:

- Guaranteed to stay free-flowing, lump free, non-dusty and packaged in multi-wall, poly-lined paper bags or totes as specified above.
- The final moisture level will be less than 10% and 99.5% product will flow through a #14 U.S./Canadian screen.
- Bulk density will be 32 ± 5 lb per cubic foot. Please notify me if oil level or carrier cause a flow problem.
- All bags or totes must be labeled with tags. Tags should include date of manufacture, lot number, guaranteed analysis, inclusion rate, and proposed use of the product.
- Formulate using the guaranteed analysis from the supplier for the nutrient. We can request label copies of your ingredients and copies of your mixing records to show quantities of ingredients per batch.

Trace Mineral Premix Specification Form

Name: _____

Product name: Trace Mineral Premix

Address: _____

Quantity, lb _____ Package size, lb _____

Phone: _____

Use level, lb/ton Sow diets: 1.36 kg

Nursery diets: 1.36 kg

Grower diets: 1.36 kg

Finisher diets: 0.68 to 1.13 kg

Fax: _____

Date: _____

Price desired (circle one) \$/lb FOB

Date Needed: _____

\$/lb Delivered

Nutrient	Units	Guaranteed Potency per lb of premix	Sources
Copper	G	5	Copper sulfate, Copper chloride
Iodine	mg	90	Ca iodate, Ethylenediamine dihydriodide (EDDI)
Iron	g	50	Ferrous sulfate
Manganese	g	12	Manganese sulfate, Manganese oxide
Selenium	mg	90	Sodium selenite
Zinc	g	50	Zinc sulfate
Carrier	%		Calcium carbonate
Oil	%		Mineral or vegetable

The following points must be followed unless approval for changes have been made:

- a) **Guaranteed to stay free-flowing, lump free with little dust, and packaged in multi-wall, poly-lined paper bags or totes as specified above.**
- b) All bags or totes must be labeled with tags. Tags should include date of manufacture, lot number, guaranteed analysis, inclusion rate, and proposed use of the product.
- c) Formulate using the guaranteed analysis from the supplier for the nutrient. We can request label copies of your ingredients and copies of your mixing records to show quantities of ingredients per batch.
- d) Trace mineral sources must comply with the AFIA Mineral Handbook as to maximum levels of arsenic, mercury, cadmium, and lead.

Vitamin Premix Specification Form – Sow Add Pack

Name: _____

Address: _____

Phone: _____

Fax: _____

Date: _____

Date Needed: _____

Product name: Sow Add Pack

Quantity, lb

Package size, lb

Use level, kg/ton Sow diets: 2.25 kg

Price desired (circle one) \$/lb FOB

\$/lb Delivered

Nutrient	Units	Guaranteed Potency per lb of premix	Sources
Biotin	mg	40	Biotin
Folic Acid	mg	300	Folic acid
Pyridoxine	mg	900	Pyridoxine HCl
Choline	mg	100,000	Choline Cl
Carnitine	mg	9,000	L-carnitine
Chromium	mg	36	Chromium picolinate
Carrier			50:50 mixture of rice hulls and limestone
Oil	%		Mineral or vegetable

The following points must be followed unless approval for changes have been made:

- Guaranteed to stay free-flowing, lump free, non-dusty and packaged in multi-wall, poly-lined paper bags or totes as specified above.
- The final moisture level will be less than 10% and 99.5% product will flow through #14 U.S./Canadian screen.
- Bulk density will be 32 ± 5 lb per cubic foot. Please notify me if oil level or carrier cause a flow problem.
- All bags or totes must be labeled with tags. Tags should include date of manufacture, lot number, guaranteed analysis, inclusion rate, and proposed use of the product.
- Formulate using the guaranteed analysis from the supplier for the nutrient. We can request label copies of your ingredients and copies of your mixing records to show quantities of ingredients per batch.

HITTING THE TARGET ON YOUR GRID

John Bancroft
Ontario Ministry of Agriculture, Food and Rural Affairs
100 Don Street, Box 159, Clinton, Ontario N0M 1L0
E-mail: john.bancroft@omafra.gov.on.ca

John Otten
Pig Info Management
219 Oak Street, Stratford, Ontario N5A 8A1
E-mail: jotten@piginfo.ca

ABSTRACT

Marketing of pigs can be considered a challenge and/or an opportunity to maximize the returns for a production system. Matching a marketing grid to a production system's goals, analyzing production and packer information, weighing techniques, and using auto sorters are some of the key items being considered as opportunities to maximize returns.

BACKGROUND

The market weight of hogs is initially determined when the production system is planned. It takes into account the pig genotype, the feeding program, the packer requirements and the expected profitability of the production system.

Each packer operates a buying schedule which is designed to ensure that a large proportion of the market hogs supplied to the plant are of the right quality and weight to meet the retailer specifications who purchase their pork products. The schedule covers a fairly wide weight range of carcasses. For example, 40 kilograms which is then further divided into smaller weight bands of 5 kilograms. The packer may set a different price for each weight band and design the settlement schedule so that carcasses which fall in a much tighter preferred weight band (the Core) receive a premium or are not discounted. Carcasses which are heavier than the Core (over weights) or lighter than the Core (under weights) are devalued according to the usefulness of the carcass to the packer.

The schedule is then further complicated as the packer also prefers carcasses with a particular level of backfat or lean meat percentage. Again carcasses which are less desirable to the packer are discounted. The two sets of bands (i.e. weight and fat or lean meat percentage) are set at right angles to form a grid where each cell of the grid has an index. When pigs are slaughtered, carcass data is automatically collected and used to generate a settlement sheet. It will show the weights and grades of all the pigs superimposed onto the settlement grid. It provides information on weight and grade of pigs, backfat or lean meat percent, yield percentage, condemnations, sort loss and finally premiums, discounts and lost opportunity. The settlement sheet may be used by management to determine the suitability of the pigs to

the particular packer contract. At farm level the sheet is particularly useful to ensure the pigs are falling within the most profitable section of the Core. The devaluing of carcasses which fall outside the preferred weight and backfat or lean meat percentage bands is termed as the “sort loss” and when averaged over all the pigs marketed may amount to several dollars per pig.

ANALYSIS

Special analyses that can measure income improvement for heavier hogs without shipping outside of the Core are valuable. In a Core window there can be a \$10.00 improvement in income over feed if we could get to the ideal weight without going over the maximum weight for that Core cell. This would be the perfect world! But, not knowing the loss or gain from precision weighing, will not serve to motivate us to continually improve the process of weighing pigs effectively. An example is provided in Table 1 based on the Ontario Heavy Market Hog grid.

Table 1. Opportunity dollars per pig.

Live Weight, kg	Dressed Weight, kg	Extra Feed Cost	Feed Conversion	Weight Class	Yield Class			
					1	2	3	4
97	77.45			4	-\$43	-\$41	-\$39	-\$38
103	82.45	\$3.01	2.87	5	-\$16	-\$15	-\$16	-\$17
109	87.45	\$3.09	2.94	6	-\$9	-\$8	-\$8	-\$8
116	92.45	\$3.22	3.07	7	-\$4	-\$4	-\$4	-\$4
122	97.45	\$3.40	3.24	8	\$150	\$147	\$146	\$145
128	102.45	\$3.68	3.50	9	-\$2	-\$2	-\$2	\$0
134	107.45	\$3.83	3.65	10	-\$27	-\$27	-\$30	-\$35

- The Core area cells for the Ontario Heavy grid are identified as Weight Classes 6, 7, and 8 and Lean Yield Classes 1, 2, 3, and 4.
- Within the Core area, the target would be weight class 8. Using the average dressed weight of 97.45 kilograms for weight class 8, index values for each yield class 1 through 4, and a market hog price of \$135 per hundred kilograms at 100 index, the gross market hog values have been calculated.
- Using feed conversion numbers from a feed curve, a feed cost per tonne of \$210 (last finishing feed); the extra feed cost (marginal cost) is calculated. This is the cost of the extra feed to move from one weight class to the next. The cost to add the extra 5

kilograms of dressed weight from weight class 7 to 8 is \$3.40 per pig based on a feed conversion of 3.24.

- The numbers shown under the yield classes 1 through 4 for the weight classes 4 to 7 and 9 and 10, are the opportunity dollars lost compared to the average market hog value in weight class 8. For example, a pig in weight class 6 and yield class 2 is leaving \$8 behind. This is the difference in the market hog values between weight class 6 and 8 adjusted for the difference in feed consumed.
- It is very clear that falling into weight class 5 or below and going into weight class 10 or above that there are a lot of opportunity dollars being lost. The challenge is trying to maximize your dollars within the Core. The important thing to remember is that the calculations are going to be different for every production system because of the variables that are involved.

The base price for hogs and the cost of feed are important considerations when looking at grids to ship your pigs on. Also, the ability for pigs to gain and convert feed are very important when considering different grids or attempting to strategically hit a specific spot on a grid. Gathering actual data on a group of pigs over a few weeks to check feed intake, average daily gain, feed conversion and weight distribution is an opportunity to verify your assumptions and fine tune the decision making process.

WEIGHING OF PIGS

A critical factor in hitting the core on your grid is obtaining the weight of the pigs in a timely and efficient matter that minimizes the stress for both the operator and the pig. Here are some points to consider:

- Individual weighing of pigs is a time consuming process but when organized correctly is probably the most cost effective way of maximizing the value of the market hog.
- Large finishing barns with more than 1200 hogs will take more time to weigh pigs as there are large numbers to put through a scale on a weekly basis.
- Proper maintenance and calibration of the scales need to take place prior to weighing pigs.
- Most weighing will be done in the aisle way. All pigs in a group are weighed and marked or grouped according to size.
- The best procedure is to weigh pigs one week ahead of the date when the pigs will be dispatched from the barn for market. These pigs are grouped together and the minimum weight is established so that at the time of dispatch pigs will be in the center of the Core.
- Determination is needed to know the exact date pigs are shipped and the average daily gain the pigs will grow for the week.
- Good communications with the processor and trucker is vital to loading pigs within a proper time frame of weighing in order for the weighing to be effective.
- Pigs can be weighed two or three weeks ahead of schedule to determine how many hogs will go to market for projection purposes. However, there is less stress on man and pigs if we can separate these pigs. These groups should be rechecked the week prior to shipping to keep the hogs in the Core. Lighter hogs can go to a week later group and heavy hogs can be shipped in the current week to avoid heavy hogs.

- More hogs are now housed in large groups of 50 or more. This makes it easier at weighing time to make groups by weight with little aggression. Hogs that are housed in groups of less than 50 will have more aggression. If mixing these pigs after weighing is done then there will be reduced gains, injuries and increased mortality.
- Barns with individual pens with small groups less than 50 should be weighed with pigs returning to their original pen and boarded out at the time of shipping. If an empty pen is available and all pigs going into this pen are strangers then there is less aggression.
- Check the settlement sheet for accuracy of weighing. Most processors can send this to the producer within two days after shipping. It is important to have this information prior to weighing pigs again for the following week.
- If it is practical, shipping pigs two times a week can be effective in getting pigs into the Core.
- It is common that a load of pigs will have an average weight within the Core. There will always be value added in a Core to place pigs as heavy as possible within the Core. This is where increased frequency of shipping per week and/or weighing pigs again prior to being loaded is needed for extreme accuracy.

AUTO SORTERS

The introduction of auto sorter technology has created opportunities and challenges to weigh and sort market hogs. Here are some observations to consider:



- Auto Sorters when managed properly have been very beneficial in reducing operator fatigue versus manual weighing.
- With large group housing, the auto sorter can go hand in hand to improve weighing results but certain procedures need to be followed.

- In an aisle way barn design, pigs need to become familiar with walking in the aisle and going through the auto sorter. Many farms allow pigs to walk into the passage and return to the pen for two to four weeks prior to weighing. They also place an old scale or the actual auto sorter in the aisle way for the pigs to walk through. At weighing time the pigs are housed so the pigs can leave their pen area, go into the passageway, through the auto sorter to be weighed, and sorted upon exit. The last 25 percent of the group may need to be encouraged into the scale in order to complete the weighing process.
- The auto sorters weighing parameters are set for the desired market weight ranges. The group that is being shipped can be run through the sorter again in order to check for pigs that have not gained the desired weight and be placed in the next week's shipping group.
- During the first weeks of weighing there is added stress to the pigs in order to make room for the selected pigs to be shipped to market. Once the barn has more square footage per pig, pigs respond well to the extra room that has been created. Care should be taken not to leave pigs crowded over a great length of time.
- Pigs should always have access to feed and water during the weighing process to reduce stress.

CONCLUSIONS

Hog marketing continues to be a challenging and evolving process. Using the tools and technology currently available, continuing to explore new technology and information as it becomes available, and using a disciplined marketing procedure assists in maximizing returns and/or minimizing opportunity losses.

REFERENCES

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GROUP HOUSING SOWS - TAKE-AWAY NOTES

John Gadd
International Pig Consultant
Scallow Cottage, Parsonage Lane, Fontmell Magna
Shaftesbury, Dorset SP7 0PB England
E-mail: jngadd@aol.com

Britain and Sweden have had to abandon keeping gestation sows in stalls due to Welfare Legislation. Denmark and parts of France are voluntarily doing so pending an overall legally enforced ban, for *all* EU countries, by 2012.

Many European pig breeders now have 15 years experience of group housing sows. Designed and managed correctly performance is little or no worse (Table 1).

Table 1. Comparison of herds with sows housed in stalls and in groups on straw.

	Stalls	Yards
Average number of sows / gilts per herd	339	260
Farrowing rate (%)	83.8	84.7
Average number of litters per sow	2.31	2.27
Average number of pigs reared per sow/year	22.29	21.46
Average number of pigs born alive/litter	10.77	10.70
Average number born dead/litter (%)	11.56	11.45
Mortality of pigs born alive (%)	10.53	11.56

Source: Easicare Yearbook 1991

While these results may seem historical, remember that since the enforced ban on stalls, little or no reliable *large-scale* 'before-and-after' comparative results involving hundreds of herds, as in the above table, were possible once stalls became illegal.

(The above table is representative of several similar surveys of the time).

CONSIDERED ADVICE FROM EUROPEAN/PIONEER EXPERIENCE

1. **Changeover.** Allow up to 3 years to research which of the six proven systems will suit you best. *Visiting successful farmers on your shortlist is essential* – advice will be freely given.

Once up and running the learning curve is about 2 years (4 to 5 parities).

2. **Choice of system.** Slats plus some bedding or fully-bedded yards? The layout is very different between the two.

3. **Dynamic or stable groups?** The management is different between them, so investigate this carefully.
4. **Size of herd?** For large herds, one of several electronic feeding layouts is preferable. For smaller herds or groups one of several systems (Dump/spin dump, Trickle, Cafeteria, Cubicle) are suitable and cheaper.
5. **Management skills.** More detailed and difficult than stalls. Expert (or experienced) and *diligent stockmanship* needed. More *time* is needed. Correct protocols essential to ensure good pig flow and sow body condition.
6. **Pen and yard design.** Research this carefully. Guard against ‘forcing’ a layout in to existing structures and floor space on grounds of conversion difficulty and cost. Large sow groups (50+) allow more flexibility in design and electronic control of pig movement and selection.

To minimize aggression, follow the advice on lying and dunging areas *implicitly* and the siting of feeding points/stations also to reduce aggression. Provide ‘fleeing space’ if possible, especially with dynamic groups.

7. **Identification.** More difficult than with stalls. Large groups lie down more/are more contented on bedding/refuse to move. Tag in each ear, spray mark for individual attention. Preg-testing is easier.
8. **Inspection.** More *time* and *patience* needed, especially for foot and udder problems. Electronic estrus identification is easy.
9. **Mixing and introduction.** Many practical skills and much experience needed, especially for gilt introduction where a mixing pen(s) of special design is/are needed.
10. **Cost?** Varies considerably due to the suitability or otherwise of existing structures. Recovered changeover costs for an excellent conversion of existing buildings for a 500 sow herd have varied in a 20% to 40% reduction in breeding herd gross margin over a 2-year run-in period (5 parities; source: - clients records 2000-2004; EU economics).

Running costs (labor, straw) are higher, vet/med lower, feed costs similar.

11. **Should you do it?** Probably not until you have to, unless your buildings need renewal or you need to expand and are thinking of 10-15 years depreciation, or your sows are in less than ideal condition. Explore (and lobby for) welfare-driven grant-aid.
12. **Does it work?** Most breeders who have converted successfully say they would never go back to stalls again, due to vastly more contented sows and happier, easier-to-recruit/train/keep stockpeople. However breeders with inadequate housing and labor skills suffer many problems until these are put right.

13. **Do the much more contented sows breed better?** Rather strangely not, or not yet. Performance results are usually no better, no worse, suggesting *good* breeders look after their stalled sows pretty well as of now.
14. **Has the move encouraged the public to buy more pork?** No. Typical response is “You shouldn’t have been keeping sows that way (in stalls) anyway.” Consumption would have dropped however if the move had not been made. The market for ‘green, organic, humane’ pork production is still a small one in Europe (7 to 9%) but growing.

ALTERNATIVE DRY SOW HOUSING

**James Osborne
Swine Genetics Ontario Inc.
8817 Glengyle Drive, RR #1
Strathroy, Ontario N7G 3H3
E-mail: jmosborne@execulink.com**

ABSTRACT

It would be safe to say that one of the next big animal welfare issues for swine will be dry sow housing. Many countries have already started to change the way sows are housed. Most noticeable is the ban on dry sow stalls in the UK. Canadian swine producers can not get caught dismissing this trend. There are organizations already at work to try and change the use of dry sow stalls. Although legislation is unlikely in Canada, pressure on large food suppliers by consumer groups or special interest groups is already happening. Group housing systems have taken hold in Canada and there are many systems that have shown success. This is no longer new technology, and Canadian producers should be looking at implementing some of the loose housing practices before it is imposed on them. By no means is a dry stall ban the answer. In fact, dry sow stalls help in the welfare of the animal being raised. A proactive approach, by producers, in finding an alternative is the best solution. If Canadian producers were to research, design and implement a new sow housing protocol that is good for the sow and the producer, which incorporates both stalls and loose housing, then consumer groups and special interest groups will have a more difficult task implementing their agenda.

CURRENT EFFORTS TO MAKE CHANGES

There is already a trend to stop using dry sow stalls. The pressure on producers ultimately comes from the public, but not always directly. In the UK consumer concern about welfare of farm animals became an issue in the 1960s. Animal welfare organizations organized quickly, obtained extensive media coverage and became extremely effective lobbyists. In response, the UK government set up the Brambell Committee to examine how livestock are kept, and if any changes should be made. Using the principles implicit in the Brambell report, the Farm Animal Welfare Council developed a basis for discussion and legislation on animal welfare that became known as the “Five Freedoms”. The Five Freedoms were later expanded with qualifying statements and these in turn formed the basis for the Code of Recommendations for Welfare of Livestock: Pigs. Despite this activity, Members of Parliament reported that they had more correspondence about animal welfare than any other issue. The construction of sow accommodation based on sow stalls and tethers was banned in October 1991, and the use of existing stall and tether systems was banned on January 1, 1999. This unilateral decision of the British government was taken ahead of any planned EU legislation. This action clearly shows that with the right pressure, governments will act.

Farm Sanctuary is a US group that helped form the initiative in Florida in 2002 amending the state's constitution resulting in a ban on gestation stalls. Although there are only a few producers in the state of Florida, this change has set a precedent that will be used in other states. Arizonans for Humane Farms has filed a petition with the Arizona Secretary of State to place an initiative on the state's 2006 ballot which would effectively ban gestation stalls. The initiative would promote legislation requiring that "pigs during pregnancy and calves raised for veal must be given sufficient space to turn around, lie down, and fully extend their limbs, when tethered, or confined in crates, cages and other enclosures..." This ballot initiative is similar to the one used in Florida and some of the same organizations are involved in putting it forward. Whether they win or not these groups will undoubtedly keep fighting within state legislatures. The Arizona fight will cost opposing farmers and ranchers over \$1 Million to fight. If these organizations continue to organize and raise funds it will just be a matter of time until they target a large hog producing state.

Safeway Inc. is the latest company to examine animal welfare issues. The company has agreed to form a committee that will consist of company employees and outside experts, including Colorado State University professor Temple Grandin. The news was hailed by People for the Ethical Treatment of Animals (PETA), which lobbied company officials for changes. PETA owns 192 shares of Safeway stock. PETA is promoting controlled-atmosphere killing (CAK), and Safeway has agreed to contact its vendors to suggest they use CAK. All food retailing companies will listen to their customers and groups representing their customers. If companies become pressured to make changes they will make changes. Dr. Bernard Rollin, an outspoken critic of large-scale livestock and poultry operations, states "the public will force changes in agriculture not through animal cruelty rules and regulations, but through the power of the purse."

A recent article was printed on pignote.com titled "Harper Government Urged to Heed New Animal Welfare Scientific Report". This report released by the Canadian Coalition for Farm Animals (CCFA) has condemned the widespread use of stalls. They believe the use of stalls threatens foreign markets for Canadian pork. Although this report was funded by special interest groups (CCFA, World Society for the Protection of Animals (WSPA)) the results are meaningful. They focused on the size of stalls and the inability for the sow to turn around. They also go on to show that the sows stay there the entire time they are mothers. They go on to say that such behavior as bar biting shows the sows are going insane.

The work being done in North America by PETA and WSPA shows that both consumer driven and legislative campaigns are making head-way.

GROUP HOUSING IN CANADA

There is fear "out there" of loose housing systems. Loose housing is looked upon as more expensive, harder to manage, and less efficient than traditional stall housing. Today the costs of each system are very similar especially if an automatic feeder is being used. Arguments can be made on either side to which system is more economical. The important message is that each housing system can be implemented without one being more expensive.

Researchers from the University of Minnesota have reported that economic losses due to culling are the same. Pen housing removes more sows due to culling, while loose housing has higher mortality. They go on to report that there was no significant difference between housing systems for pigs born alive or pigs weaned. Chris Cockle from Heronbrook Farm LTD operates a 950 sow unit using loose housing. He states “the management of sows in this system is easy: vaccinating, and preg-checking for instance. The 19 square feet I calculate is the absolute minimum. The recommended number of 25 sq. feet is probably more appropriate, and would still be cost effective in comparison to stalled systems.” Any new system, especially if you are changing systems, will have to be approached differently when it comes to management, feed, genetics, and facility.

Alberta Agriculture, Food and Rural Development (AAFRD) is working with many industry partners on group sow housing. The research compares three different sow-housing systems and a gestation stall system. Each with a different feeding strategy, one includes free access stalls in which the animals can access a protected feed stall at their choosing. Another features a dual-level mezzanine system with feed stalls that provide no protection at feeding but provide a slightly larger floor area thanks to a second-floor mezzanine. Another incorporates an electronic sow feeder where sows are protected at feeding but can only be fed one at a time. Differing grouping systems will also be studied. In terms of behavior, the research team has chosen to focus on aggression in the initial mixing of the groups as it is the behavior that can have the most impact on health and productivity. The team will be looking at sow longevity in each system as well as reproductive performance. Kelly Lund, Engineer-in-Training for AAFRD is on the research team and she recommends that producers starting an enterprise should seriously consider a group housing system, if for no other reason than it is the direction the industry and the market opportunities are headed. This research will be very interesting to follow. It is very comprehensive and should have a lot of conclusions to offer on the comparison of these different systems.

I mentioned earlier I believe the dry stall still plays a very important role in a loose system. With loose housing you will still have sows that get too fat or too thin. By putting these types of sows in stalls, the proper body condition can be reached through individual feeding. Sows will still show some aggression which leads to boss sows and timid sows. If a sow is too aggressive or too timid, they can be placed into a stall for individual attention. These sows may mix better into other groups. Breeding AI is very efficient when the sows are in stalls. Sows are often fed differently during breeding and often need individual attention. By leaving any of these types of sows in a loose system with no where else to put them, is poor animal welfare practice. These reasons are why I think a dual system would work.

BEING PROACTIVE

It is very important for producers to not sit idle and hope nothing happens. The first step should at least be getting educated about the “no stall” issue. Dialogue between producers, producer groups, Canadian Pork Council and provincial ministries (OMAFRA) would certainly be the next step. These groups are in the best position to determine the best course of action on this issue. This step will undoubtedly be the most difficult. Many producers

believe that stalls offer excellent welfare and will not want to deviate from a 100% stall system. In order to move past this, producers will have to change their thinking to how welfare practices are perceived by the consumer. If the stance is developed to change to a combined stall and loose system, it will have to be based on research. How many stalls as a percentage of the population? How long can they stay in the stall? How wide should the stalls be? How long should the stall be? These are some of the questions that need to be answered. If the stall/loose housing system is what producers want to adopt, I think all the questions would be answered very quickly. Keeping an eye on such research, as that from Alberta, will help bolster the stall/loose housing system, from a welfare point of view. If producers feel a 100% stall system is an acceptable animal welfare practice, they better have data to support it and be prepared for a fight. The cost to fight a stall ban is in the millions, so being proactive and implementing a new code of practice that doesn't include a total ban looks good. Being proactive and implementing a producer driven change could also allow for more desirable "phase" in periods than that of an imposed stall ban. If the Canadian pork industry were to voluntarily implement a new code of practice for housing sows that included stalls and loose housing, I believe it would gain great respect across the world, including special interest groups.

CONCLUSIONS

With the increased efforts of special interest groups trying to ban stalls, and succeeding in some areas, producers need to start acting. The industry needs to organize and implement housing changes that are beneficial to all involved (the consumer, the producer, and the sow). I believe a housing system that allows for stalls along with loose housing is the best for the sow, and the industry in the long run. We can debate the welfare issues all we want, but the simple fact is 100% stall housing is a welfare issue no longer acceptable with consumers. If producers do not want to see a total ban on stalls, then efforts must be made now to show loose housing, with the availability of stalls, is positive for the welfare of the sow. Through research data and a proactive attitude, a new welfare code of practice could be put in place without a total stall ban that is accepted by everyone. Producers, producer groups, the Canadian Pork Council, federal and provincial agriculture ministries need to come together and address this issue before it is too late.

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NEW APPROACHES FOR CONTROLLING NURSERY DISEASES... OR BACK TO THE BASICS?

John Harding
Department of Large Animal Clinical Sciences
Western College of Veterinary Medicine
University of Saskatchewan
52 Campus Drive, Saskatoon, Saskatchewan S7N 5B4
E-mail: john.harding@usask.ca

INTRODUCTION

In spite of our well-intentioned vision, the implementation of many novel health improvement technologies in the last 2 decades, such as “high health”, all-in-all-out (AIAO), segregated early weaning, and off-site production, has failed to eliminate diseases from our modern nurseries. Furthermore, the emergence of new diseases such as porcine circovirus (PCV2) and porcine reproductive and respiratory syndrome virus (PRRSv) has been catastrophic in some instances, and a persistent nuisance in many others. Swine nursery diseases will continue to evolve. They will have significant impact on the lives of production and veterinary personnel, and ultimately reduce productivity and competitiveness.

So does the solution to our nursery disease issues depend on the development of novel technologies, or in re-focusing on good husbandry and production practices? This is a difficult question to answer, but Rose et al. (2003) has demonstrated that the latter was responsible for controlling PMWS in France. Furthermore, the PMWS outbreaks in Sweden, a country blessed with an excellent productivity and health status, appear to be related to significant managerial problems, shortened cycle times and poor hygiene (Wallgren et al., 2005).

There is no doubt that good production practices (GPP's) reduce the impact of nursery disease. Conversely, multi-sourcing, poor air quality, overcrowding and poor hygiene enhance disease expression. In this new PRRS+PCV2 era, the management practices of the past may not be good enough to ensure future success. The objectives of this paper are to outline the production and managerial practices I believe, from a western Canadian perspective, are most influential in controlling nursery diseases.

WESTERN CANADIAN NURSERY DESIGN AND OPERATION

The design and management of nursery units in Western Canada are variable. While most nurseries operate AIAO by room, both on- and off-site nurseries are common. By contrast, AIAO by building or site are rare. With the rapid development of larger sows units (2000⁺ sows), the west has largely avoided multi-sourced off-site nurseries. Weaning ages typically range from 16-28 days and weaning weights 5-8 kg. At present, there is an upward trend in weaning ages in order to improve post-weaning performance. Large companies employ specialized nursery technicians; many of which have minimal to no hog experience. However,

these individuals are trained to be highly competent swine technicians internally and/or by industry backed training programs. Smaller units, including the Colonies, generally have experienced and efficient herdspeople in key areas of the barn such as the nursery. However, the use of standard operating protocols at the farm level is variable. The biosecurity and location of nurseries, particularly of larger units is good but by no means perfect. Garden-variety diseases and conditions including the suis-ides (*Haemophilus parasuis*, *Streptococcus suis*, *Actinobacillus suis*, erysipelas), PRRS (low-virulence), swine influenza, post-weaning diarrhea and arthritis are problematic in some herds, but catastrophic disease outbreaks are rare. One to two per cent is still an achievable target for nursery mortality on many farms.

EIGHT “BASIC” FACTORS CONTRIBUTING TO THE FUTURE SUCCESS OF NURSERY UNITS:

1. **Number of sources:** In my opinion, the single most important factor contributing to the health stability of western Canadian nurseries is the avoidance of multiple sourcing. Fortunately, western Canada missed the revolution that encouraged expansion by relocating weaned piglets to off-site communal nurseries. For a number of reasons, the western industry developed larger sow units that support stand-alone single-sourced nurseries. In general, the risk of disease increases proportionately with the number of sources. To properly manage multiple source nurseries, the health status of each sow farm must be compatible, and this is by no means an easy task.
2. **Location of the nursery and upstream sow units:** Many regions of the west continue to benefit from isolation and excellent locational biosecurity. On the flip-side, isolation increases transportation costs, and may hinder the availability of good labour. While the aerosol transmission of many respiratory diseases including mycoplasma, swine influenza, and porcine respiratory corona virus is undisputed, there is considerable debate with respect to the aerosol transmission of PRRS. Equally important but less understood is the relationship between hog density and disease transmission via fomites (inert objects) and biological vectors (rodents, flies, birds). In hog dense areas, rigid external biosecurity protocols are needed to prevent fomite- and vector-associated transmission, because there are so many opportunities and sources of cross-contamination.
3. **Sow herd stability and passive immunity:** There is no question that sow herd stability is imperative for controlling diseases such as PRRS, that are potentially transmitted from sow to piglets during pregnancy. Moreover the importance of sow stability in ensuring consistently high levels of passive immunity has become increasingly apparent. Passive or colostral immunity protects newborn piglets for 4-6 weeks, during which time the adaptive immune system is primed. The colostrum of parity one females (i.e. farrowed gilts) typically contains lower antibody levels than the colostrum of mature sows. Thus, high gilt replacement rates tends to lower passive immunity at the herd level, alter the dynamics of colonization and increase the risk of disease occurring later in life. Parity segregated production appears to enhance health and productivity by these mechanisms. Thus, a healthier population results which partially explains the popularity of parity segregation for the control of mycoplasma (Moore, 2005) and PRRS (Hollis, 2005).

Enhancing passive immunity is also one of the approaches used to control PMWS. Boosted pre-farrowing PCV2 vaccination is an effective method of reducing clinical disease, lesions, viral load and PCV2 shedding in nursery-aged pigs in France and Germany (Charreyre, et al., 2005).

4. **Pig flow:** Most nurseries in western Canada are designed to operate AIAO by room. However, effective health control can only be accomplished if the AIAO flow is strictly maintained in all farrowing and nursery rooms. In general, more barns could improve in this regard by reviewing hold back policies, fostering practices, and eliminating transfers between rooms. Thus, pig flow is best described as “broken” AIAO system; where too often the movement of animals among rooms potentially introduces new diseases into clean populations. Equally important, is the reluctance of farrowing staff to euthanize sub-optimal and compromised pigs, in favour of transferring them to the nursery.
5. **Coinfections:** While the “high” health status of western Canada is a tremendous advantage, it is being eroded with time. Intensification has eliminated some pathogens, but encouraged others. Disease control protocols in the future will require addressing multiple coinfections rather than single agents. Continued societal pressure will reduce the availability and perception of mass prophylactic antimicrobial usage, but encourage the development of novel vaccination technology such as oral and needleless delivery.
6. **Human resources:** The pig business is a people business. Well-trained and dedicated human resources are a huge asset. Recruiting and keeping skilled staff is one of the biggest issues facing the western Canadian industry today, particularly in regions competing with the oil industry. Ironically, economic development and the creation of new jobs is one of the main drivers behind the continued development of many large hog facilities in remote prairie towns, particularly in Saskatchewan and western Manitoba. Large specialized facilities provide competitive salary & benefits, technical challenge and lifestyle for persons looking to supplement farm incomes, and to those looking for rewarding careers in the swine industry.
7. **Management systems:** The most successful swine businesses in western Canada have developed effective and efficient management systems. All management must be capable of analysing performance data, identifying problems and implementing solutions in a timely manner, *simply to keep up with the industry*. In this highly competitive, commodity based industry the management factors that will drive future success will be cost control, human resources management and innovation. Average management will generate average returns.
8. **Effective Standard Operating Procedures (SOP's):** Regardless of their form, effective SOP's are living documents that reflect the best practices on the farm. SOP's should not quench new ideas, but should eliminate the use of sub-par production practices. Every farm should have written protocols or SOP's that outline the farm's best practices, *and a monitoring system to evaluate compliance*. Ultimately, all barns should be operated as per these SOP's, which may also serve as valuable training documents. Many of the routine production and health issues I see in barns are directly linked to the absence of or non-

compliance to SOP's that detail *basic basic* good production practices. This reflects an unfortunately high prevalence of management failure in our industry, and a huge opportunity for the future.

Standard operating procedures or written instructions should be available for:

- Sanitation and downtime
- Wean age & weight (average, variation)
- Environmental control (temperature, air quality, humidity standards)
- Pen size and density
- Feeding (diets, feeder space, frequency of feeding)
- Treatment, vaccination and euthanasia guidelines

CONCLUSIONS

In summary, there are many excellent nursery units in Canada; and Ontario is no exception. Hats off to these producers! But the swine industry is technologically advanced and competitive. New diseases have emerged and capitalized on the flaws or weaknesses in our management systems. How does your nursery rank? My advice is to look after the basics; provide solid management, promote good production practices, and streamline pig flow, and the rest will fall into place.

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NEW APPROACHES TO WEANER ROOM MANAGEMENT

John Pluske
School of Veterinary and Biomedical Sciences
Murdoch University
Murdoch WA 6150, Australia
E-mail: J.Pluske@murdoch.edu.au

ABSTRACT

Weaner room management encompasses the physical aspects of the nursery such as the correct temperature and lighting, the correct management of water and feeders, correct feeding strategies, an appropriate duty of care for sick and poor-performing piglets, and the filling and emptying of the nursery space. Incumbent should be an understanding of the growth and biology of the young pig and the effects of factors such as group size and stocking rate. Nurseries differ in many of these factors, but the unifying principle of most nurseries is the need to hit a mean target weight in an assigned time whilst minimising mortality and morbidity. This applies equally to wean-to-finish nurseries and nursery-only operations. This paper discusses several aspects of weaner room management in light of these principles.

INTRODUCTION

Charbonneau (2005) provided an excellent review concerning the treatment and management of poor-doing pigs at last year's conference. Of interest in the nursery are possible reasons why pigs perform variably in the period after weaning, and inherent in understanding this is nursery room management. However, a breakdown of which pigs perform best after weaning shows that not all pigs are equal, and that weight at weaning is not the sole predictor of subsequent performance. This paper discusses some particular factors that can influence post-weaning management and performance.

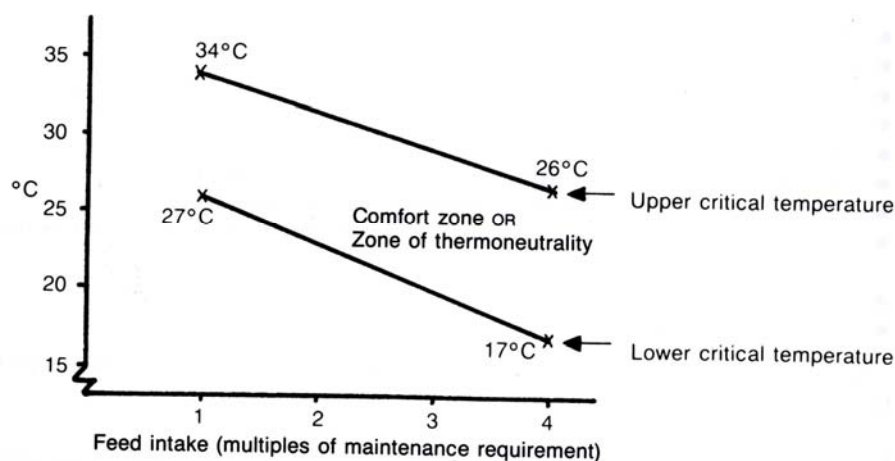
THE CORRECT ENVIRONMENT

A major cause of post-weaning trauma and a contributor to variation in weight gain is a poor environment. Dritz (2004) and Charbonneau (2005) have described the key elements associated with a sound nursery room for entry of pigs. Attention needs to be paid to factors such as ventilation, lighting, humidity, sanitation, space and flooring, the creation of a suitable microenvironment (if needed), water flow/quality, and feeders. Having done this, the next task is to ensure that the room is functioning efficiently, and temperature management is critical in this.

Temperature and Feed Intake

A key inspection aim in the nursery should be assessment of piglet behaviour, not the thermostat outputs, because observing the pigs will often provide clues as to whether a problem exists. In the post-weaning period where voluntary feed intake is low and often insufficient to meet the pigs' maintenance requirements, the temperature of the room can have a profound influence on the efficiency of growth and development, the incidence and severity of disease, and immune function (reviewed by Madec et al., 2003). The lower critical temperature (LCT) is defined as the ambient temperature at which, for a given energy intake, energy retention is maximal. The LCT corresponds to the 'optimum' temperature at weaning in as much as the main goal is to minimize heat loss to avoid excessive loss of body lipid, thereby minimizing the decrease in thermal insulation (Madec et al., 2003). The combination of low energy intake and a reduced body thermal insulation at weaning causes a temporary increase in the LCT (at pig level) from 22-23° C at weaning to 26-28° C in the first week after weaning (Le Dividich et al., 1980). Moreover, and as Figure 1 demonstrates, the LCT of pigs kept in groups of 10 and at maintenance feed intake is approximately 27° C, and can go as high as an upper critical temperature (UCT) of 34° C before problems may occur. Pigs eating more feed, or multiples of maintenance of feed (energy), have a reduced LCT, so that stimulating higher levels of feed intake after weaning is an obvious means to reduce the temperature requirement for newly-weaned pigs and save heating costs, eg, less days using heat lamps. I am unaware of any research investigating the LCT of weanling pigs kept in pens of 30-50, however it is probable that there would be little or no reduction in the LCT because pigs can huddle equally as effectively, thus minimizing the surface area from which heat can be lost. Comfort can be assessed quickly and easily by the rule-of-thumb that half the pigs should be sitting up and the other half lying on their sides (Charbonneau, 2005).

Figure 1. Upper and lower critical temperatures of pigs weighing 5 kg kept in groups of 10 on mesh flooring and on different levels of feed/energy intake (Bruce, 1982; cited by English et al., 1988).



It is essential, therefore, that pigs are maintained in their zone of thermal comfort so that absorbed nutrients are used for body growth and not thermogenesis, although anecdotally I

have heard that some producers deliberately lower night time temperature of nursery rooms to stimulate pigs to eat, once the stress associated with weaning has abated. There is some research to support this notion because there is a circadian rhythm in metabolic rate that is lower during the night (Madec et al., 2003), and Shelton and Brumm (1988) showed that a 4-9° C reduction in nocturnal temperature does not negatively impact upon pig performance but markedly decreases heating costs (Table 1). Data from Kurihara et al. (1996) suggests that a fluctuation of $\pm 3^{\circ}\text{C}$ around the mean daily temperature does not impact upon performance after weaning. Collin et al. (2001) modelled the effects of a high, constant temperature on food intake in young growing pigs and reported that during the overall post-weaning period, food intake starts to decline markedly at ambient temperatures higher than 25° C. This underscores the importance of reducing nursery room temperatures once pigs start to consume 2-3 times their maintenance energy requirement, which is generally achieved after the second week post-weaning. Monitoring the prevailing nursery ambient temperature at pig level after the first couple of weeks should be included as part of routine management in nurseries.

Table 1. Effect of reduced nocturnal temperature (RNT) during the nursery phase on pig performance^a (after Shelton and Brumm, 1988).

Treatment	Control (° C)	RNT (° C)
Average daily gain, g	340	360
Average daily feed intake, g	530	570
Feed:gain (kg/kg)	1.57	1.61

^a256 pigs per treatment, initial body weight 6.7 kg. Pigs were exposed to either a constant regime (30 ° C for 1st week reduced by 2° C/week for 4 weeks) versus a cycling daily temperature regime (same temperature as Control in 1st week but night temperature lowered to 22 ° C on week 2 and further by 2 ° C/week thereafter).

Sanitation

Dritz (2004) has previously summarized the principles and benefits associated with proper cleaning, disinfection and drying of nursery rooms prior to the pigs' arrival. Deterioration of sanitary conditions limits growth and induces a moderate immune response, however there is relatively little data demonstrating the effects of 'bad' sanitary conditions on production and biology after weaning. Le Floc'h et al. (2006) used pairs of littermates weaned at 4 weeks of age, with pairs housed either in a 'clean' environment and fed an antibiotic-supplemented diet, or housed in unsanitary rooms, mixed with non-experimental piglets, and fed a diet devoid of antibiotics. Not surprisingly, pigs kept in the 'bad' environment performed worse than pigs kept in the 'clean' environment, and displayed higher plasma concentrations of haptoglobin (an acute-phase protein), copper, vitamin B₁₂ and lysine but lower concentrations of glutathione, pyridoxal-5-phosphate (coenzyme for amino acid metabolism), folic acid, threonine and tryptophan. Poor sanitation in the nursery appears to affect performance by modifying nutrient utilization and activating the pigs' defence system, reiterating the need for attention and vigilance when it comes to preparation of nurseries.

As another example, Dritz (2004) remarked that drying time in nurseries was longer in the latter winter and early spring and if an allowance (eg, cleaning a day earlier) is not made for

this, then pigs can be placed into nursery spaces with moist surfaces and humid environments that could, in turn, exacerbate the post-weaning check. Together, these data reiterate the importance of managing the nursery in accordance with the prevailing conditions. Newly weaned pigs will take longer to adapt to a poor unhygienic environment and will alter their metabolism and immune function accordingly.

SORTING AND MIXING PIGS

Mixing of unfamiliar pigs at weaning causes aggression and fighting as pigs seek to establish dominance hierarchies. It is common to see pigs fighting in the first 1-6 days after weaning, with some pigs having scratches over their face and flanks displaying the spoils of battle. But is this behavior detrimental? Many studies have been conducted quantifying fighting behaviours and establishment of the social order, but as a reflection of both the time-consuming nature of such research (usually necessitating small groups) and the period when the research was conducted (1970s, 1980s, where large pens were not used), the relevance of this research to today's production systems is questionable. In Australia for example where weaners can be placed into deep-litter (barley/wheat straw or rice hulls) shelters (hoops) in groups exceeding 250, the relevance of establishing a social order and subsequent effects on production is spurious because pigs can hide and (or) run away from any dominant pigs. Our own research (Pluske and Williams, 1996a) showed that mixing unfamiliar pigs at weaning caused fighting but no adverse effects on production, whereas co-mingling non-littermate piglets during lactation (which is still practised by some producers) or treatment of pigs at weaning with a psychotropic compound reduced aggression (and stress) but failed to improve production indices. Regardless, mixing of pigs at weaning inevitably occurs and the associated fighting is simply accepted as part of the process. Nevertheless, vices after weaning are of welfare concern and should be monitored. Main et al. (2005) conducted a study to investigate the impact weaning age (12, 15, 18 and 21 days of age, n = 2,272) had on belly-nosing behaviour and umbilical lesions after weaning. Belly-nosing behaviour and umbilical lesions were less frequent as weaning age increased, with nosing activity and umbilical lesion scores nearly doubling as weaning age decreased from 15 to 12 days.

Should I sort pigs? Conventional wisdom suggests that sorting pigs into similar weight groups will reduce variation in subsequent growth, but evidence to support this notion is equivocal. Dritz (2004) suggested that in multi-site production systems with a fairly narrow weaning age window per group, there is no advantage in growth performance to sorting by weight categories upon initial placement into the nursery. Brumm (*pers. comm.*) suggested that once a pig is placed in a pen then the only way out is at sale, if it's suffering from bleeding or major injury, or if it is dead. Nevertheless many producers use hospital pens or sick pens to care for poor-doing pigs, and both Dritz (2004) and Charbonneau (2005) have provided tips as to how best manage such piglets.

GROUP SIZE AND STOCKING RATE

Changes in production systems in the last 10-15 years have seen a re-examination of the recommendations for group size and stocking rates for pigs. Group size (number of pigs per pen) is an important factor in the design and management of facilities for pigs as it can influence capital requirement, welfare, and performance. Groups of 30 in commercial practice were previously considered as large, whereas today groups of 100 to 1,000 pigs are used on some farms. In a recent paper, Payne et al. (2006) reviewed the literature on group size and performance for weaner (and also grower and finisher) pigs and, across studies, these authors surmised that increasing group size from 5 to 100 pigs per pen appeared to have a small, negative effect on performance provided that floor space, and the number of feeders and drinkers supplied, was adequate. Both growth rate and feed intake decreased slightly but with little effect on feed efficiency. Payne et al. (2006) suggested that in practice, the economic consequence of increasing group size would depend on relativities between prevailing construction, labour and feed costs. Housing pigs in large groups decreases construction, maintenance and cleaning costs, but may increase labour associated with inspection, treatment and marketing of pigs. Feed efficiency is unlikely to be affected greatly, although slight decreases in growth rate may reduce throughput or sale weight marginally. In Australia for example, the construction of deep-litter systems for pigs between weaning and finish is a cheaper option than concrete and steel and suits the contract nature of such operations.

An important element of the post-weaning environment is feeder design and feeding behaviour, and in this regard group size and/or stocking rate can have an impact. Two recent studies have investigated various aspects of group size, stocking rate and interactions with feeders in nursery pigs. Smith et al. (2004) determined the effects of group size and feeder trough opening in nursery pens on performance by conducting a study with 3 group sizes (16, 20 or 24 pigs per pen, providing 0.35 m², 0.28m² or 0.23 m² per pig, respectively) and 5 feeder gap openings (9.2-31.5 mm) with a trough-type feeder. These authors found that increasing space from 0.23 m² to 0.35 m² per pig increased body weight gain, and that optimal growth and feed efficiency was seen when the feeder gap opening permitted 25-60% of the feeder trough to be consistently clear of feed. Smith et al. (2004) surmised that the capacity of a nursery feeder space was 11 pigs when the feeder gap opening allows 25-60% of the feeder trough to be clear of feed. These data reinforce the observations made by Charbonneau (2005), but also show that space allowance has an impact on feeding behavior and growth.

In a wean-to-finish production system, DeDecker et al. (2005) used 1,296 pigs to evaluate 3 stocking rate treatments (22, 27 or 32 pigs per pen, with floor and feeder spaces per pig of 0.78 m² and 4.2 cm, 0.64 m² and 3.4 cm, and 0.54 m² and 2.9 cm, respectively), between weaning (15 ± 1 days of age) and 24 weeks after weaning. From week 8-18, week 18-24, and overall from weaning to week 24, both daily gain (688, 660 and 635 g/day for the overall period, respectively) and body weight (121.8, 117.1 and 113.1 kg at week 24, respectively) decreased linearly with increased stocking rate, as did mortality and morbidity rates. DeDecker et al. (2005) concluded that in such systems, decreasing group size and thereby increasing floor and feeder space per pig had beneficial effects on performance.

FACTORS ASSOCIATED WITH NURSERY PIG PERFORMANCE

A recent study from the Ontario Veterinary College (de Grau et al., 2005) aimed to determine the association between body weight of pigs at 7 weeks of age, specific management factors, and previous body weight. A total of 3,736 pigs from 8 commercial farms were used that varied in size from 150-1,200 sows and included farrow-to-finish pigs, farrow-to-feeder pigs, and off-site nursery units. Data gathered included age, sex and clinical disease, the number of pigs per pen, feeder spaces, water access, pen space per pig, and regrouping of pigs. All-in/all-out (AI/AO) by room or by nursery was practiced on 5 of the 8 farms, with the other 3 farms being continuous flow (CF). Weaning age varied between 14 and 29 days of age with a mean of 19.7 ± 3.7 days, however weaning age data were analysed and piglets were classified either as 'early' (17.2 ± 2.9 days), 'moderate' (21.2 ± 1.5 days) or 'late' (27.4 ± 1.1 days) with respective weaning weights of 5.2 ± 1.3 kg, 6.1 ± 3.7 kg and 6.9 ± 1.9 kg. At a standardized age of 7 weeks, pigs from the 3 weaning age groups weighed 16.5 ± 3.8 kg (CV 23.4%), 13.6 ± 3.2 kg (CV 23.6%) and 12.8 ± 3.0 kg (CV 23%), respectively.

De Grau et al. (2005) found that birth weight and weaning weight both had a significant influence on nursery pig performance (Table 2), accounting for 12.7% and 4.7% of the total variation, respectively. Light-weight pigs (< 4.1 kg) entering the nursery had a higher rate of death/culling (49.6%) and were lighter at 7 weeks of age than pigs weighing more than 5.8 kg, again underpinning the importance that weaning weight as a whole has on subsequent post-weaning performance. Rates of gain after weaning were greater in AI/AO farms compared to CF farms.

Table 2. Factors associated with weight of nursery pigs at 7 weeks of age (after de Grau et al., 2005).

Variable ^a	Coefficient ^b	Standard error	Partial r^{2c} (%)	P value
Intercept	7.08	0.70	-	<0.001
Birth weight	1.58	0.16	4.7	<0.001
Weaning weight	0.80	0.04	12.7	<0.001
Standard weaning age	-0.86	0.28	0.4	<0.01
Late weaning age	-2.60	0.38	2.2	< 0.001
AI/AO flow	5.42	0.93	0.3	<0.01

^aFarm and sow nested within farm were included as random variables.

^bIndicates the predicted change in the 7-week weight as the variable changes by 1 unit, eg, if weaning weight increased by 1 kg, the 7-week weight increases by 0.8 kg.

^cIndicates the proportion of the variation in 7-week weight explained by the variable, eg, changes in weaning weight accounted for 12.7% of the total variation in 7-week weight.

An obvious outcome from the work of de Grau et al. (2005) was that better/different management strategies are needed in the post-weaning period for lightweight pigs than medium- and heavy-weight pigs. This is supported by relevant physiological data concerning light-for-age pigs (see Dunshea, 2003). An obvious strategy at the point of sorting is to place

all pigs below a pre-determined weight/size into pens together and possibly treat these differently to heavier pigs, such as with liquid/gruel feeding or a continuation of feeding the most nutrient dense diet beyond the usual period of time. The need to optimize throughput and minimize variation in weight at slaughter in swine facilities has highlighted the problem that slower growing, lightweight nursery pigs present. Variability in post-weaning growth performance should ideally be minimized in order to maximize space utilization, especially in AI/AO systems (Becker, 1998).

FEEDING IN LACTATION AND POST-WEANING FEEDING AND GROWTH

The problem of suboptimal intake of feed (and hence energy and nutrients) and water after weaning needs no explanation or reiteration, and is partly the focus of my other paper in these proceedings. It is little surprise that pigs seem disinterested in feed and water given the simultaneous stressors that they have just been exposed to, yet the industry generally expects pigs to reach target weights in set times despite the perturbations that occur. But can we predict post-weaning performance of individual pigs based on pre-weaning characteristics?

Can We Associate Milk and Creep Feed Intake in Lactation with Post-Weaning Performance?

The young sucking pig has little control over its food (milk) intake (rate and total sum) and will consume all the nutrition that the dam can provide. It is evident that at some point during early- to mid-lactation the ability of the sow to satisfy the capacity of her piglets for intake of her milk is exceeded. One would predict, anthropomorphically perhaps, that piglets would then seek out other sources of nutrition to counteract the reduced quantity of milk they receive per suckling episode. This is part of the rationale for providing 'creep' feed or supplemental milk liquid diets. Additionally, it might be anticipated that familiarity with feed and water before weaning would be advantageous to the pig after weaning with respect to both commencement of feeding and gastrointestinal adaptation, however there is an overall lack of compelling evidence to support this notion.

As a consequence of the weaning process, there is enormous variation between individual piglets in feeding-associated factors such as latency to first meal, rate of feed intake, and the pattern of feed intake (summarised by Brooks and Tsourgiannis, 2003). Some pigs can take up to 54 hours to take their first meal even though pen mates were already consuming feed, suggesting that some individual pigs, for whatever reason(s), simply maladapt to their new feeding environment. One philosophy always recommended is to provide enough feeding space so that pigs learn to eat together – but does this facilitate quicker adaptation to feed?

This is a tough question to answer. Morgan et al. (2001) examined whether 'experienced' weaned pigs, with respect to eating, transferred their knowledge about eating to 'inexperienced' (newly weaned) pigs. These authors presented some evidence that the presence of 'experienced' pigs with 'inexperienced' pigs facilitated eating behavior sooner, but the study had very large variation between individual pigs. Similarly, Brooks and Tsourgiannis (2003) remarked that pigs that suckled together in lactation tended to approach

the feeding trough together after weaning, but this did not necessarily mean that eating occurred. Nevertheless, and as explained previously, it is crucial to provide enough trough feeder space so that if a pig wants to eat, it can.

Not unexpectedly, therefore, numerous articles and reviews (eg. Dritz, 2004 and Charbonneau, 2005) describing the importance of feeding behavior and management after weaning have been written, even though we still appear to understand some aspects very little. Attention to non-eating pigs would appear to be crucial, although Dritz (2004) claimed that with proper nursery management the number of pigs requiring attention (i.e. active intervention) is 2-4%. In this respect, Dritz (2004) provided a 'checklist' for stockpersons in identifying the poor-doing pigs.

Is it always the lightweight pigs that don't eat though? English et al. (1988) presented data showing that pigs failing to thrive after weaning were on average the 'lighter' ones, but some of the 'heavier' pigs also give problems (Table 3). In this study, when the 10% of pigs that performed 'best' were compared to the 10% of pigs that performed 'worst' in the 28 days after weaning, it can be seen that among the 'best' 10% were some light pigs while among the 'worst' 10% were some heavy pigs. The 'best' 10% were only 23% heavier than the 'worst' 10% at weaning at 18 days, however this difference had ballooned to 150% after 4 weeks, indicating that for one reason or another, the 'worst' 10% failed to adapt adequately to the post-weaning system. English et al. (1988) stated that pigs failing to handle the transitions at weaning should receive preferential treatment and could be fostered back to the sow (unlikely these days), kept in a warmer environment, offered a higher quality diet and/or be left on a starter diet and the first stage of rearing accommodation for a longer period of time. Hospital/sick pens could also be employed. In units where there are some but not too many poor-doing pigs, English et al. (1988) advised one of two strategies: improve the whole system for the most vulnerable pigs or leave the general system as it is for the great majority of the pigs and strengthen part of it for the small minority of problem pigs. Modern-day production dictates that the latter strategy is generally employed, except in worst-case scenarios where the entire weaning system requires an overhaul.

Table 3. Comparison of the best 10% and the worst 10% of pigs in a sample of 150 pigs weaned at 18 days of age (after English et al., 1988.)

	Live weight at start, kg		Live weight gain, g/day			
	Mean	Range	Week 1	Week 2	Week 3	Week 4
Best 10%	5.59	4.6-7.4	105	240	544	589
Worst 10%	4.54	3.6-6.6	-38	85	164	61
	Live weight, kg					
Best 10%	5.59		6.33	8.01	11.82	15.87
Worst 10%	4.54		4.27	4.87	6.02	6.35
LW benefit of Best 10%	23%		48%	64%	98%	150%

The influence of weight at weaning into the nursery on subsequent performance is not linear even though straight lines are often seen in data sets and ‘rule of thumbs’ are commonly used to underscore the relationship. On a population (room, pen) basis this generalization holds true, however these data reveal that whilst we generally consider pigs above a certain weight to better handle weaning than pigs below this weight, a proportion of the heavier pigs still fail to thrive after weaning. De Grau et al. (2005) reported that sow-to-sow variation explained a greater proportion of the variation in 7-week weight than farm-to-farm differences, and although stockpersonship and other farm variables likely impact on 7-week weight, these were overwhelmed by the within-farm variation (de Grau et al., 2005). Perhaps, and as I allude to in the next section and in my other paper, we need to identify factors back in the production chain that might assist our understanding in this area.

But can we identify the poor-doing pigs before weaning? And if so, would this be of any benefit? Piglets that suck from the posterior teats seemingly grow slower than those sucking from teats anterior to these and so tend to be lighter at weaning (Pluske and Williams, 1996b; Kim et al., 2000). Pigs are not equal at birth with respect to birth weight, the functionality of the mammary glands is not uniform and, combined with the lower ability of small pigs to compete at the udder and extract milk, it is little wonder that more of the small, lightweight pigs struggle. When sucking piglets are given the opportunity to be curious with dry feed and eventually eat some of it, usually at weaning ages greater than 26 days, there is some evidence that piglets sucking a less productive teat will consume creep feed more readily than their counterparts sucking anterior (more productive) teats (Brooks and Tsourgiannis, 2003). At Murdoch University, we have modified a technique developed in The Netherlands that uses a dye as a fecal marker to classify piglets as ‘good eaters’, ‘moderate eaters’ or ‘non eaters’ of creep feed during lactation.

Using this methodology with pigs weaned at 31 days of age, we (Kim et al., 2005a, 2005b) observed that piglets categorized as ‘good-eaters’ at the end of lactation had numerically lower daily gains in the first 12 days of lactation (238, 248 and 253 g/day for ‘good’, ‘moderate’ and ‘small-eaters’, respectively) and tended to occupy the posterior teats. After weaning on day 31, the growth rate of ‘good eaters’ was maintained indicating no reduction in feed intake, however between days 34 and 38 the production of ‘good eaters’ declined markedly (due to diarrhoea, as no antimicrobials were in the diet). The growth rate and intake of ‘small-eaters’ decreased immediately after weaning but this was associated with a reduced incidence of diarrhoea, while production in the ‘moderate’ eaters was intermediate. Piglets suckling anterior teats grew 40 g/day more than piglets sucking the posterior teats up to weaning (278 g vs. 237 g/day, respectively), but after weaning, the growth rate of piglets suckling anterior teats decreased to day 34 but started to recover from day 38 onwards. In contrast, piglets suckling posterior teats maintained their growth rate after weaning and between weaning and day 59 of age, grew faster than piglets sucking from the anterior teats. These data suggest that piglets not consuming ‘enough’ creep feed suffer a growth check up to 4 weeks after weaning, and confirm that piglets sucking from the posterior teats consume the most creep feed but this is insufficient overall to boost their growth rate to the level of their counterparts drinking from the more anterior teats. Ironically, the consumption of more milk in lactation in piglets drinking from anterior teats may actually limit the intake of creep

feed that, in turn, exacerbates the post-weaning growth check. But whether or not this is related to a 'poor-doing' pig in the nursery remains to be elucidated.

CONCLUSIONS

Weaner room management, even before the pigs even arrive, is a pivotal part of ensuring a good start for young pigs. Good stockpersonship is critical to the success of managing the nursery. Systems that assist the poor-doing pigs, whilst taking some time and effort, should be considered.

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A PRACTICAL LOOK AT NUTRITIONAL ATTEMPTS TO IMPROVE PORK QUALITY

**Bob Goodband, Joel DeRouchey, Mike Tokach,
Steve Dritz, and Jim Nelssen
Department of Animal Sciences and Industry
Kansas State University
242 Weber Hall, Manhattan, Kansas 66502
E-mail: goodband@ksu.edu**

ABSTRACT

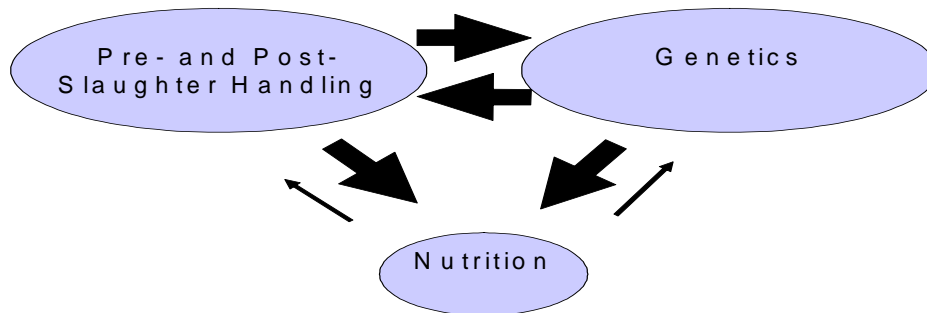
When one reviews the literature examining the effects of diet on pork color, water-holding capacity, and other quality indicators, results are highly variable. It is not uncommon to find one or two studies where manipulating the diet improved some aspect of pork quality, and find at least as many studies where the same experimental factors yielded no change at all. Factors such as genetics and pig handling before and after slaughter will be much more important in influencing pork quality than nutrition.

INTRODUCTION

Nutrition is frequently considered an important factor affecting pork quality; however, it is essential to realize that it plays a relatively minor role compared to genetics and pre- and post slaughter handling. Furthermore, genetics and especially pig handling around the time of slaughter could also be considered as dominant factors compared with nutrition (Figure 1). For example, pigs fed properly and with the genetic potential for excellent pork quality traits, can still exhibit a higher than average incidence of poor pork quality if they are improperly handled around the time of slaughter. In this example, good nutrition and genetics might be able to mitigate a very minor portion of the detrimental effects of poor handling, but they are certainly not going to be able to totally overcome the effects of poor handling. Likewise, excellent handling around the time of slaughter and good nutrition may only offset a minor percentage of the problems associated with genetic predisposition for poor pork quality (i.e. Halothane and Napole genes). Providing pigs a magical concoction of nutrients prior to slaughter will not be enough to over-ride the potentially negative effects of genetics or pig handling around the time of slaughter.

Because pre- and post-slaughter handling and genetics play such a dominant and over-riding role compared with nutrition on pork quality, this is probably the reason why nutrition/pork quality research is so variable. Specific combinations of factors involved with an individual experiment may create a situation where a dietary nutrient may elicit an improvement in pork quality. However, when replicated in a second experiment, handling around the time of slaughter or genetics may not be identical, and thus the particular response is not duplicated.

Figure 1. Relative importance of pre- and post-slaughter handling, genetics, and nutrition on pork quality. Arrows indicate the relative degree that one characteristic can dominant any potential contribution of a different characteristic.



Therefore, as the swine industry moves towards producing a product with improved color, firmness, and water holding capacity, this will necessitate that genetic suppliers, production systems, and pork processors work together to standardize as many of their practices as possible. Then, once stability has been achieved from beginning to end, this will provide the framework in which to fine-tune and evaluate nutritional manipulation of pork quality. Because of the increase in development of case-ready, and(or) branded products, and the ever increasing export of pork from North, Central, and South America to the rest of the world, enhanced pork quality by adjusting components of the entire production process, not just nutrition, will become critical for pork production systems to succeed.

DEFINITIONS OF PORK QUALITY

An issue not previously mentioned in the discussion of pork quality that can also represent a potential source of variation is its actual definition. Pork quality can have many different meanings to different people within the pork production chain (Table 1; adapted from Coma, 2001). Furthermore, these individual aspects of pork quality may require very different solutions to achieve them. Areas such as food safety and social implications of pork production will prove to be formidable challenges in the future considering changes in global population and economic status.

Carcass Characteristics

One area frequently associated with pork quality is carcass leanness. Obviously, under- and to a lesser extent over-feeding lysine will affect carcass lean to fat ratio. It has been thought by some that perhaps purposely under-feeding lysine in the late finishing stage of growth may increase intramuscular fat (marbling) and therefore produce cuts of pork with greater tenderness and juiciness. However, this strategy has serious production implications. Recent research suggests that unlike the growing pig (25 to 75 kg), slightly underfeeding lysine in late finishing (75 kg and above) has by far a greater negative impact on gain and feed

conversion (Main et al., 2002). In that study, feeding 10% and 20% below the pig's estimated requirement for only a 4-week period added \$0.72 and \$2.48 in added feed cost, respectively. This does not take into account the negative effects of increasing the number of days needed in finishing space or the revenue lost by selling lighter pigs. Furthermore, it would appear to take approximately 5 weeks of feeding a low lysine diet to achieve increased longissimus marbling (Cisneros et al., 1996), and improvements in marbling appear to be offset by poorer water holding capacity and tenderness (Goodwin 1995). The economic incentive to produce pork carcasses with above average marbling would need to be extremely large to offset the added production costs in the majority of commercial production systems.

Table 1. Various aspects of pork quality (adapted from Coma, 2001).

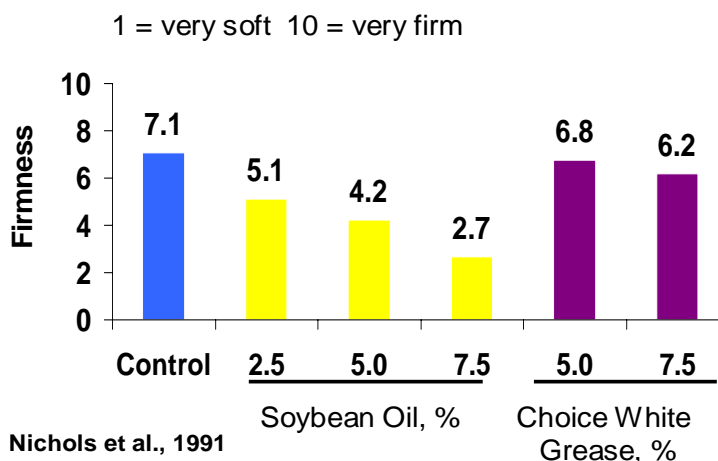
Item	Attribute
Food Safety	Microbiological hygiene: absence of Salmonella, Campylobacter. Absence of residues: Antibiotics, growth promotents, metals, pesticides, etc.
Eating Quality	Tenderness, juiciness, flavor, and smell Quantity of visual fat, degree of marbling. Cooking losses.
Nutritional Value	Quantity of fat and composition of fatty acids. Protein content. Vitamins and Minerals. Enrichments.
Technological Quality	Carcass and fat firmness, pH, water holding capacity, tissue separation, oxidative stability (shelf-life).
Social Quality	Animal welfare, environmentally responsible, business structure (large vs. small farms).

Fat Characteristics

Another aspect of carcass characteristics relating to pork quality is not only the amount of but also the chemical characteristics of the adipose tissue. It is well known that pigs deposit fat very similar to the composition of dietary fat consumed. Therefore pigs fed a diet high in unsaturated fatty acids typically exhibit carcasses with what is referred to as "soft pork". Soft pork results in a number of problems including: difficult fabrication and in particular slicing of bellies for bacon, increased separation of fat layers and muscle, fat smearing in processed pork, and pork cuts that are less firm and undesirable to the consumer. The effects of feeding finishing pigs (55 to 110 kg) increasing choice white grease or soybean oil on carcass firmness is presented in Figure 2 (Nichols et al., 1991). In that study, increasing soybean oil decreased carcass firmness, but increasing choice white grease had relatively little effect. Woodworth et al. (1999) observed that finishing pigs fed 6% poultry fat had bellies that were significantly less firm than pigs fed no added fat, whereas pigs fed 6% choice white grease had intermediate belly firmness. Engle et al. (2001) observed similar trends in pigs fed choice

white grease and poultry fat; however, in that study, feeding only 4% of either fat source did not appear to as negatively affect belly firmness as feeding 6% fat.

Figure 2. Effect of fat source on carcass firmness.



Danish Meat Research Institute standards for fat firmness recommend an Iodine Value (IV, measure of the degree of unsaturated fatty acids with the higher the value the higher the degree of unsaturated fatty acids) of pork to be no more than 70. Boyd et al. (1997) suggested that many pigs fed corn-based diets would exceed this standard, and recommended an IV of 74 with a dietary maximum of 2.1% linoleic acid (C18:2).

For these reasons, feeding unsaturated fat sources such as soybean oil and poultry fat should be minimized or in the very least the duration of feeding monitored. Data from Wiseman et al. (1993) suggests that it takes approximately 25 to 30 days to observe a shift in fatty acid profile. However, more research is needed evaluating the effects of different feeding durations and sequencing strategies with predominately unsaturated vs. saturated fat sources.

A nutritional supplement that has a consistent and dramatic effect of fat firmness is conjugated linoleic acid (CLA) or modified tall oil (also a source of conjugated C:18 2 isomers). Either of these compounds improves carcass firmness by increasing the percentage of saturated fatty acids deposited compared with unsaturated fatty acids (O'Quinn et al., 2000a). Should either of these compounds be fully cleared for use in swine feed and if the appropriate economic incentive was in place, it is likely that they would be used because there is little question regarding their efficacy in improving belly firmness.

Because the pig will deposit fat similar to its dietary composition, the possibility of producing pork products with specific "nutraceutical" characteristics such as greater than average concentrations of a specific fatty acid or fat soluble compounds is not outside the realm of possibility. However, it is probable that such marketing strategies would rely heavily on smaller scale niche markets.

Within the past two years the issue of fat color has gained in research interest. This has to deal with the potential, that carotenoids and other fat-soluble pigments, primarily in yellow dent corn, negatively affect fat color. Recent studies would suggest no differences in pork longissimus or fat color scores between pigs fed yellow and white corn (Fent et al., 2003), or yellow or white corn, and barley (Lampe et al., 2003a,b,c). Based on these recent studies it would appear that primary grain source has little overall impact on pork or fat color.

NUTRITION FACTORS INFLUENCING PORK QUALITY

Feed Withdrawal

The practice of withdrawing feed from pigs 12 to 18 hours before slaughter should result in emptying of the stomach and gastrointestinal contents. This will result in less potential carcass contamination from accidental cuts to the gastrointestinal tract during evisceration, a food safety concern. In addition, feed withdrawal may decrease the glycogen reserve of muscles at slaughter. Less glycogen would result in less conversion to lactic acid and therefore a high ultimate pH. Binder et al. (1998: as cited by Ellis and McKeith, 1999) observed that meat color and pH was improved for pigs held off feed if they were homologous recessive for the Napole gene. In pigs that carried the dominant allele, feed withdrawal had no effect. However in a second study there was no benefit at all to feed withdrawal. The authors indicated that in the first study, pigs were regrouped and mixed at the time of feed withdrawal, whereas in the second study they were not. Therefore, they speculated that the stress and possible glycogen depletion from fighting during the mixing period was also a variable that had to be considered.

Other factors to consider with feed withdrawal are how to effectively remove the pig's access to feed as well as knowing when the majority of pigs have last eaten. Fasting for greater than 24 hours will result in tissue loss. These factors combined with potential transportation delays as well as variable lairage times at the packing plant make feed withdrawal as a means to improve pork color a difficult challenge.

Vitamin E

Without question the most widely studied nutrient on affecting pork quality is vitamin E. Vitamin E is speculated to enhance pork quality by two possible mechanisms (Pettigrew and Esnaola 2000). The first is that antioxidants such as vitamin E inhibit the conversion of oxymyoglobin (red color) to metmyoglobin (brown color). This would result in maintaining acceptable pork color for longer durations of storage. The second proposed hypothesis is that antioxidants like vitamin E help maintain cell membrane stability, which reduces drip loss and oxidative rancidity. Feeding high levels of vitamin E has been observed to produce pork with a darker color and the ability to maintain color stability longer than non-supplemented controls. Vitamin E supplementation has also been shown to reduce drip loss and lipid oxidation. However, it is important to point out that these beneficial effects on pork quality do not become apparent until tissues have become "saturated" with vitamin E. Asghar et al. (1991) suggests a minimum tissue alpha-tocopherol concentration of at least 2.6 ug/g tissue

before color, lipid oxidation, and drip loss will be enhanced, whereas some studies found tissue levels as high as 4.0 ug/g to be required. Therefore, dietary concentration of vitamin E and duration of feeding appear to play an important role in its effectiveness. Unfortunately, most studies have evaluated no added vitamin E or a relatively low concentration of vitamin E compared with a very high (200 mg/kg of feed) level and for relatively long durations. Unless additional studies are conducted to determine if a lower dosage or shorter feeding duration is equally as effective as the 200 mg/kg dosage commonly used in past studies, using vitamin E to enhance pork quality will be economically unjustified with current pork pricing programs. Interestingly, Waylan et al. (2002) observed that pigs fed modified tall oil (a source of conjugated linoleic acids) in conjunction with 110 mg/kg of vitamin E improved display color stability and reduced lipid oxidation to a greater extent than vitamin E alone. Results of O'Quinn et al. (2003) verified that modified tall oil increases the vitamin E concentrations of adipose and other tissues.

Vitamin D

Studies in beef cattle have shown that feeding high concentrations of vitamin D improves beef tenderness. Vitamin D increases plasma and muscle calcium concentrations, which in turn stimulates activity of calpains. Calpains are intracellular proteases, which have been shown to enhance meat tenderness. Enright et al. (1998) fed finishing pigs 331, 55,031, and 176,000 IU/kg of vitamin D₃ for 10 days before slaughter. Increasing vitamin D decreased daily gain (0.77, 0.67, and 0.07 kg/day) and daily feed intake (3.82, 3.63, and 2.90 kg/day). However, subjective color, Hunter L* values, and firmness improved and drip loss decreased with increasing vitamin D. Wiegand et al. (2002) fed pigs 500,000 UI vitamin D for three days before slaughter. Hunter L* values decreased and a* values increased indicating a darker, redder color after 14 days of storage. However these differences, although significant were of such a small magnitude that they were undetectable by subjective scoring. Although not statistically significant, daily gain was reduced over 50% in pigs fed high vitamin D during the three-day test period. Pork tenderness was unaffected by dietary treatment. While studies in beef cattle have seen improved tenderness with vitamin D supplementation, studies in pigs show some improvement in pork color but not tenderness. One must consider if the changes in pork color may be more of a result of the severe reduction in feed intake for several days before slaughter rather than a response attributable to vitamin D itself.

Vitamin C

Vitamin C can be metabolized into oxalic acid which has been shown to inhibit glycolysis and in turn improve pork quality (Kremer et al., 1998). In a subsequent trial, Kremer et al. (1999) fed 783 or 2348 ppm of added vitamin C for four hours before pigs were slaughtered. Short-term feeding of added vitamin C improved color scores and reduced drip loss. Providing pigs vitamin C via the drinking water for 48 hours increased plasma ascorbic acid concentrations during supplementation (Pion et al., 2003.). However, ascorbic acid and oxalic acid values quickly returned to those of control pigs when supplementation ended and there were no differences observed at the time of slaughter. No differences were observed in pork color, drip loss or lipid oxidation. Feeding added vitamin C for five days before slaughter actually increased (worsened) lipid oxidation in irradiated pork samples (Ohene-Adjei et al., 2001).

Magnesium

Supplemental magnesium has been shown to reduce catecholamine and cortisol concentrations in plasma and reduces skeletal muscle activity. Therefore, supplementing Mg to the diet should reduce the pigs glycolytic potential resulting in a high ultimate pH and improved color and water holding capacity. Some studies have shown positive responses to Mg supplementation (Otten et al., 1992; Schaefer et al., 1993; D'Souza et al., 1998, 1999; and Apple et al., 2000). These studies usually provided a bolus of Mg from one of several different sources for a short period before slaughter.

However, several studies have reported no benefit to various sources and forms of Mg supplementation (O'Quinn et al., 2000b; Frederick et al., 2003a,b,c; Hamilton et al., 2003). Such discrepancies in research findings again emphasize that other factors such as pre- and post slaughter handling and genetics must also play a greater role in pork quality than nutrition. Therefore, before implementing a nutritional strategy to improve pork quality it is imperative that it be evaluated under the conditions of your particular production chain.

Iron and Manganese

Longissimus pH and 24h L*, a*, and subjective color, marbling, and firmness scores were not affected by feeding an added 90 ppm of Fe sulfate or chelated Fe (in addition to 40 ppm of Fe sulfate in the trace mineral premix), but added Fe from either source reduced drip loss 10 to 15% (Saddoris et al., 2003). Roberts et al. (2002) observed improved color and less lipid oxidation with increasing dietary manganese up to 350 ppm, but addition of 700 ppm had no beneficial effects. In a subsequent study, added dietary manganese from up to 320 ppm had no affect on pork color or drip loss (Roberts et al., 2003).

Niacin

There has been limited research studying the effect of added niacin on meat quality. Piva (1995) reported higher reflectance values of semimembranosus muscle when feeding 75 mg/kg of added niacin to 160 kg pigs for 7 days prior to slaughter. This would indicate a greater denaturation of myoglobin, and a redder color. The authors also reported higher marbling scores when pigs were fed 150 mg/kg of niacin.

Recently Real et al. (2002) examined the effects of increasing dietary niacin on growth performance and pork quality. The first study was conducted in a university research facility with 2 pigs per pen and added niacin had minimal effects on longissimus quality measurements, although some numerical trends were apparent. The second experiment was conducted in a 1,200 head commercial research facility with 25 pigs per pen (Table 2). Added dietary niacin significantly improved meat quality, similar to the numerical trends in the first experiment. The reason for the greater response in the commercial environment is maybe due to the differences in feed intake (2.4 kg in the university environment vs. 2.1 kg in the commercial environment). Feeding added dietary niacin at 110 or 550 mg/kg niacin appeared to give the greatest response when evaluating pork quality. This was most evident in Exp. 2, especially when evaluating subjective color scores, L* values, and 24-hour pH.

Table 2. Effects of niacin on growth performance and loin quality in grow-finish pigs raised in a commercial environment (Real et al., 2002).

Item	Added dietary niacin, mg/kg						SEM	Contrasts, P <		
	0	13	28	55	110	550		Niacin ^a	Linear ^r	Quadratic
D 0 to 117										
ADG, g ^b	760	775	762	775	754	753	6.1	0.58	0.06	0.48
ADFI, g ^c	2168	2154	2141	2070	2064	2075	27.0	0.03	0.05	0.01
G/F ^c	0.35	0.36	0.36	0.38	0.37	0.37	0.004	0.01	0.20	0.01
Longissimus										
Color ^{def}	3.9	3.8	3.9	3.3	4.2	4.4	0.19	0.86	0.01	0.89
Marbling ^g	1.1	1.2	1.2	1.4	1.3	1.6	0.21	0.39	0.15	0.73
Firmness ^h	2.4	2.4	2.5	2.3	2.4	2.6	0.18	0.75	0.42	0.82
Wetness ^{ij}	2.4	2.6	2.4	2.4	2.7	2.9	0.13	0.15	0.01	0.45
Drip loss, % ^e	2.00	1.90	1.93	1.90	1.23	0.80	0.469	0.39	0.04	0.41
L* ^{bj}	53.12	53.60	53.14	53.95	51.43	49.77	0.733	0.36	0.001	0.35
a* ^e	8.22	7.57	8.00	8.15	8.07	7.27	0.374	0.33	0.10	0.54
b* ^e	13.33	13.15	12.90	14.24	12.89	12.35	0.404	0.61	0.04	0.76
45 min pH	6.42	6.42	6.32	6.28	6.29	6.32	0.127	0.51	0.76	0.38
24 hr pH ^{ij}	5.67	5.73	5.77	5.76	5.85	5.94	0.049	0.01	0.001	0.06

^aControl vs. added niacin.

^bQuadratic (P < 0.06) when comparing 0 to 110 mg/kg niacin.

^cLinear (P < 0.002) when comparing 0 to 110 mg/kg niacin; 0 vs. 550 mg/kg (P < 0.02).

^dScoring system of 1 to 5: 3 = reddish pink, 4 = purplish red, and 5 = purplish red.

^e0 vs. 550 mg/kg (P < 0.10).

^fLinear (P < 0.06) when comparing 0 to 110 mg/kg niacin.

^gScoring system of 1 to 10: score represents % intramuscular fat.

^hScoring system of 1 to 3: 1 = soft; 2 = firm; and 3 = very firm.

ⁱScoring system of 1 to 3: 1 = exudative, 2 = moist, 3 = dry.

^j0 vs. 550 mg/kg (P < 0.01).

Drip loss percentage of the longissimus was reduced when pigs were fed 550 mg/kg added niacin. Therefore, when evaluating niacin requirements of finishing pigs based on pork quality, these data suggest that 110 mg/kg added dietary niacin will improve pork quality, with further improvements at 550 mg/kg niacin. Certainly, more research is needed to evaluate the influence of these higher levels of dietary niacin on pork quality, but they also point out differences in magnitude of response between university and commercial research environments.

Creatine

Creatine is an amino acid derivative normally produced by the liver, kidneys and pancreas from arginine, methionine, and glycine. Its function is to provide high-energy phosphate for the conversion of ADP to ATP following rapid energy expenditure, usually in the form of muscle contraction. In humans, creatine supplementation has been observed to reduce muscle fatigue and enhance performance during anaerobic exercise. Because of its role in cellular energetics, it is speculated that creatine might delay postmortem glycolysis and delay the associated drop in pH. Intracellular phosphates bound to creatine may also increase water-holding capacity. Supplemental creatine has been observed to decrease drip loss of longissimus measured 24 hours post slaughter; however results are variable in that one level of creatine or its feeding duration will reduce driploss, then values will return to those similar to controls with a different dose or duration (Berg and Allee 2001; Stahl et al., 2001; James et al., 2002). O'Quinn et al. (2000c) and Stahl et al. (2003 a,b) observed few if any improvements in pork color or driploss in pigs fed creatine.

Carnitine and Ractopamine

In 1999, Ractopamine HCl (Paylean) was approved by the FDA for use in finishing pig diets in the U.S. Extensive research has shown that Paylean improves growth performance and carcass leanness in pigs by directing nutrients away from fat deposition and towards lean deposition. The increase in protein deposition is very rapid during the first two weeks when Paylean is fed. During this time, it is possible that pigs may be in an energy-dependent phase of growth, and are not consuming enough feed to maximize protein deposition. Because of its role in fatty acid utilization, adding carnitine to the diet could increase the amount of energy available for protein deposition and increase the response to Paylean. In addition, carnitine has been shown to increase flux through pyruvate carboxylase and decrease lactate dehydrogenase in pigs. Therefore adding L-carnitine to the diet may increase pH and decrease drip loss, and thus improve meat quality. James et al. (2003a) conducted four finishing trial examining the effects of added Paylean and (or) carnitine in finishing pig diets. There were a total of 2,152 pigs used and two of the trials were conducted in university research facilities and two were conducted in a commercial research facility. The growth performance data from treatments of L-carnitine (0 or 50 ppm) and Paylean (0 or 9 g/ton) from the four trials were combined (Table 3). There were no carnitine \times Paylean interactions ($P > 0.27$). Feeding pigs Paylean improved ($P < 0.01$) average daily gain and feed efficiency in these experiments. A trend was observed for increased average daily gain ($P < 0.07$) when pigs were fed carnitine compared to controls. Pigs fed carnitine in the last three to four weeks of the finisher phase also had improved ($P < 0.01$) feed efficiency compared to

pigs not fed carnitine. These results suggest that L-carnitine and Paylean improve growth performance of finishing pigs.

Table 3. Interactive effects of L-carnitine and paylean on finishing pig growth performance in four trials (James et al., 2003a)^a.

Item	Paylean, g/ton				SE	Probability (<i>P</i> <)		
	0		9			Carnitine x Paylean	Carnitine	Paylean
	Carnitine, ppm							
	0	50	0	50				
ADG, kg	0.90	0.95	1.03	1.04	0.02	0.27	0.07	0.01
ADFI, kg	2.65	2.65	2.66	2.62	0.05	0.60	0.61	0.73
F/G	2.97	2.82	2.62	2.54	0.04	0.40	0.01	0.01

^aValues are means of thirty-three replications from four different experiments with 2, 2, 22 to 26, and 18 to 19 pigs per pen in Exp. 1 through 4, respectively. Treatment diets were fed for 28 d in Exp.1, 2, and 3 and for 21 d in Exp. 4.

In three of the four studies, loins were collected and analyzed for standard carcass measurements, visual analyses of longissimus muscle color, marbling, and firmness, color spectrophotometry (L^* , a^* , and b^*), drip loss, ultimate pH, and temperature at 24-h postmortem. A carnitine \times Paylean interaction ($P < .02$) was observed for visual color, L^* , and a^*/b^* in Exp. 1. In pigs fed Paylean, increasing carnitine decreased L^* and increased visual color scores and a^*/b^* compared to pigs not fed Paylean. Ultimate pH tended to increase (linear, $P < .07$) with increasing carnitine. Drip loss decreased (linear, $P < .04$) in pigs fed increasing carnitine. In Exp. 2, a carnitine \times Paylean interaction was observed ($P < .04$) for visual firmness and drip loss. Visual firmness scores decreased in pigs fed increasing carnitine and no Paylean, but increased with increasing carnitine when Paylean was added to the diet. Drip loss decreased with increasing levels of carnitine when fed with Paylean. In Exp. 3, pigs fed carnitine tended ($P < .06$) to have decreased drip loss.

The improvements in meat quality of pigs fed L-carnitine in combination with Paylean may be the result of carnitine's affect on the pigs' metabolic parameters either antimortem or postmortem. Carnitine has been shown to increase pyruvate carboxylase and decrease lactate dehydrogenase in pigs. An increase in pyruvate carboxylase may direct pyruvate away from lactate, thus reducing substrate for lactic acid synthesis postmortem. Furthermore, a decrease in lactate dehydrogenase may delay the onset of postmortem glycolysis. In theory, this would result in an increase in pH, and therefore darker color, better water holding capacity, and decreased drip loss. When results are compared across the three individual trials, it appears that there is a greater improvement in driploss due to added carnitine in diets containing Paylean than without (Figure 3 and 4).

Further research needs to be conducted to better understand the effects and metabolic action of carnitine on antimortem lactate levels and postmortem glycolysis. However, if further studies confirm pork quality benefits, such as decreased drip loss, increased pH, and improved

meat color, or decreased serum lactate levels, the potential exists for dietary L-carnitine to be used in conjunction with Paylean in the late finishing phase.

Figure 3. Effects of added L-carnitine (0 or 50 ppm) on longissimus drip loss (diets without Paylean: James et al., 2003b).

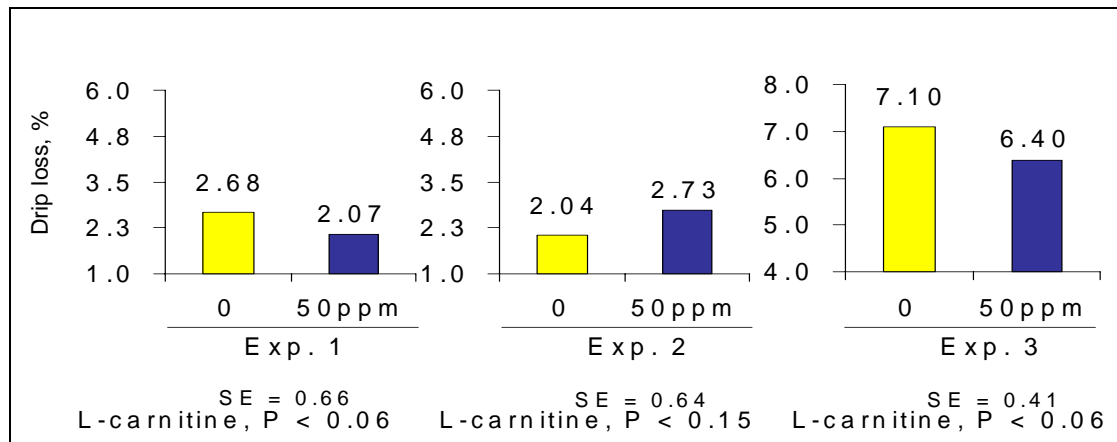
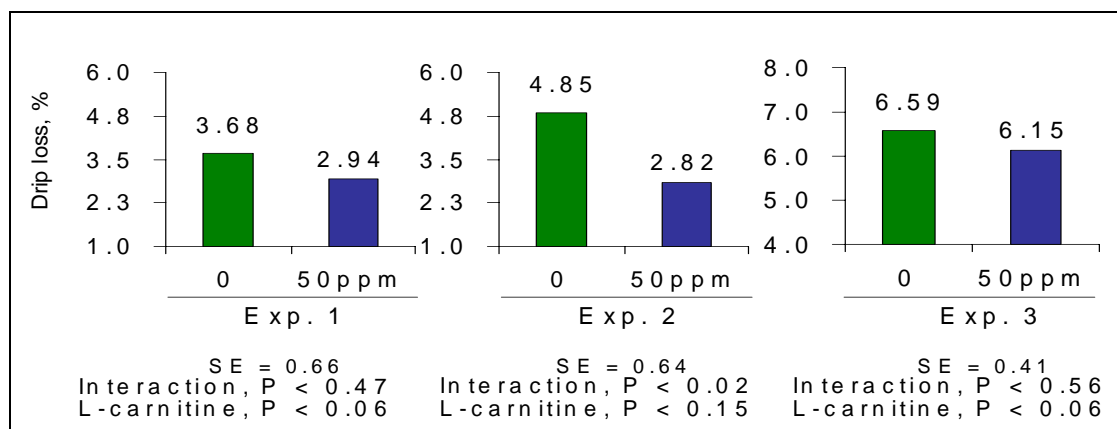


Figure 4. Effects of added L-carnitine (0 or 50 ppm) on longissimus drip loss (diets with 9 g/ton Paylean: James et al., 2003b).



CONCLUSIONS

1. There are several definitions of “pork quality”. A production system needs to communicate with their clientele to determine which criteria are important, and also the economic ramification from a production standpoint to implement such changes.
2. Nutrition/pork quality research is highly variable. Therefore, nutritional attempts to improve pork quality may be highly specific to a particular live animal production-packing plant system.

3. Again it is important to remember factors such as genetics and pig handling before and after slaughter will be much more important in influencing pork quality than nutrition. As our industry moves towards more and more “pumped” pork, arguable nutrition will play even less of a role in pork quality.
4. Although not as important as pre and post harvest handling, arguably there needs to be some “minimal” nutritional standard in place so as not to send an inferior product to the packing plant.

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WHAT PRODUCERS CAN DO TO IMPROVE MEAT QUALITY: THE GENETIC APPROACH

Andy Robinson

**Centre for Genetic Improvement of Livestock
Department of Animal and Poultry Science
University of Guelph, Guelph, Ontario N1G 2W1
E-mail: andyr@uoguelph.ca**

ABSTRACT

Traditional methods of genetic improvement have yielded long-term, significant improvement in traits relating to production efficiency and overall carcass quality; traits like growth rate, feed conversion, leanness and loin muscle area. These methods require widespread data collection and analysis for continued success. Traits associated with end product or consumer product quality have not received as much emphasis up to this point. These traits are costly to measure and require sampling from or cutting into parts of the carcass. New technology for selecting on molecular genetic markers (marker assisted selection, MAS) will unlock the potential for selecting for these new traits. By taking the costly measurements on smaller groups of pigs and associating differences in the traits with specific markers, the markers can become the selection tool eliminating the need for collecting costly trait data on a large number of pigs. Specialized terminal sire lines can be developed to target a variety of market characteristics and grading grids.

INTRODUCTION

The Ontario swine industry has been very successful in breeding and exploiting superior genetics to improve meat quality. So much so that the time has probably come to take stock of where the industry is and where it should be going. The industry is changing, most dramatically in the marketing and processing of commercial hogs. As the number of hogs sold on the basis of carcass specifications increases, the challenge of successfully marrying genetics and nutrition to produce the hog best suited to a specific grid is becoming more widespread. While it is theoretically possible to follow a genetic selection program to design the optimal hog for each grid, in practice this would be a waste of time and resources. Realistically, the grid specs can change much faster than a genetic program so the game would always be played in catch up mode to the frustration of all involved. Instead, the direction to take with genetic improvement is not going to be a single path. As an industry, we need to design a program that combines both maternal and paternal characteristics that creates a flexible, adaptable and profitable means of producing hogs for different market needs. Breeders will be working on a variety of lines with specific characteristics and documented performance results. Commercial producers will be working with seedstock suppliers to design the best combination of boars and gilts for market opportunities that are available. The fine tuning of these combined genotypes to hit the target grid(s) can then be done through feeding and management.

GENETIC IMPROVEMENT SUCCESS

Valuable lessons can be learned from what has gone before. The industry's success at improving meat quality has focused on traits related to production efficiency and overall product quality. Reducing the amount of fat in the carcass overall increases feed efficiency while at the same time addressing the consumer's growing interest in lean products. Reducing the amount of fat in the carcass has also enabled our industry to increase carcass weights and still achieve acceptable levels of fat on the heavier carcasses. However, this success has been quite uniform in nature. By measuring backfat depth and selecting for reduced backfat, breeders have been removing fat from the entire carcass. The Canadian Centre for Swine Improvement statistics indicate a genetic improvement of the lean yield of the Yorkshire carcass by 0.32%, the loin eye area by 0.4 sq. cm., reduced the age to 100 kg (increased growth rate) by 6.8 days, improved feed conversion by 0.09 kg of gain per kg of feed and reduced backfat by 0.57 mm between 2000 and 2005 (CCSI, 2006). Similar statistics for the Duroc reveal genetic improvement of the lean yield of the Duroc carcass by 1.03%, the loin eye area by 2.31 sq. cm., reduced the age to 100 kg (increased growth rate) by 7.6 days, improved feed conversion by 0.12 kg of gain per kg of feed and reduced backfat by 2.05 mm between 2000 and 2005 (CCSI, 2006). This translates into a change in market hogs of lean yield of the carcass by 0.07%, the loin eye area by 1.5 sq. cm., reduced the age to 100 kg (increased growth rate) by 6.9 days, improved feed conversion by 0.102 kg of gain per kg of feed and reduced backfat by 1.38 mm between 2000 and 2005 CCSI, 2006. The estimated value of this improvement in market hogs at \$1.85 per hog in facility overhead savings from faster growth, \$2.17 in reduced feed consumption and \$0.82 more per hog for lean yield for a total increase in value of \$4.84 per hog for the difference between 2000 and 2005 genetics.

All of these improvements, even when looking at just the last five years, represent a dramatic improvement in carcass value. Looking back over longer time frames shows that the trend started slowly in the 1960's with the introduction of performance recording. The trend grew stronger in the 1970's as technology like ultrasound was used to measure leanness of the live animal and, grew stronger again in the 1980's when genetic improvement statistics like estimated breeding values (EBVs) became widely available through the Federal-Provincial Record of Performance program (Kennedy et al., 1986). In the 1990's and new millennium, the trend dramatically accelerated as the number of traits increased and the integration of the data collection and data analysis systems added more value to the information being provided.

Today, the tools are available within the regional-national improvement system to custom tailor genetic improvement programs for a full spectrum of general or specific selection goals (De Vries, 1989; CCSI, 2006). Information is also available to support decision making for choosing replacement stock for commercial production systems with specific targets. So, at this point there are resources in place to assist us to achieve a variety of genetic improvement and seedstock selection goals.

GENETIC IMPROVEMENT DIRECTIONS

Noticeably absent from this discussion is any mention of consumer product quality. One can argue that reduced fat is a component of consumer product quality. A counter argument is that our motivation as an industry for reducing carcass fat was a combination of reducing fat in the product and improving production efficiency because lean hogs convert feed better; fat is expensive to produce. So addressing fat as a consumer product characteristic was only part of the goal when reducing carcass fat. As an industry, there has not been significant investment of genetic improvement resources to address consumer product quality traits such as marbling, meat colour, flavour, tenderness, water holding capacity, pH and other measures of meat characteristics that affect consumer product quality. At the same time, there is a challenge to define quality from the consumer perspective when production systems potentially have both domestic and international markets (Ngapo, 2005). Product quality data is expensive and difficult to collect and with varying definitions of quality, the benefit to building a selection and production program around consumer product quality is difficult to identify. All of the traits that have been the focus of an improvement program so far have been traits that can be measured easily and relatively cheaply on the live animal either directly or indirectly using non-invasive technology like ultrasound.

So, here we are with an efficient system of genetic improvement and aggressive uptake of new genetics by commercial producers. This system works well with our traditional traits but it is time to look to the future and determine how best to work on traits that are much more closely related to product quality.

While accurate predictions of the future are limited to expensive phone calls advertised on late night television, extrapolating from existing trends and observing trends in other countries and commodities may give some idea of what the future holds for pork. One very clear trend is the segmentation of the marketplace, this is being experienced by many commodities. Each year a greater percentage of pork is being processed on the basis of a specification for a particular carcass. Some of these specifications include traits that we do not routinely consider in our genetic programs like colour and marbling (Webb, 2005). As these characteristics find widespread inclusion in carcass specifications, the economic incentive for genetic improvement that has been missing up to this point is now in place. A missing component so far has been economic return for investment in genetic improvement of meat quality traits. It is clear that the carcass specification trend will continue and it is very likely that there will be more meat quality characteristics that become part of the specifications. Now that the economic picture is becoming clearer, how can genetic improvement chase a moving target?

Adapting will take some new approaches on the genetic improvement side and will mean some new information for commercial producers to use to select their replacement stock. Breeding programs have long been specialized into maternal and terminal sire lines (Moav and Hill, 1966). Production systems are generally based on crossbred females bred to terminal sires to produce market hogs. Female lines are selected for fertility as well as (but with less emphasis overall) current production and carcass traits. These female lines are crossed to produce females with hybrid vigour for reproductive traits to maximize piglet production. These crossbred females are then bred to a terminal sire boar to create the commercial hogs

for market. Although variations exist on this theme, it is a generally accepted production system, even within vertically integrated operations.

Within this general production system, the female resources represent a significant investment at all levels. Therefore rapid genetic change in female lines to respond to differences in carcass characteristics is probably next to impossible and definitely economically unsound (Smith, 1985). Longer term trends can and should be built into the female selection program but short term adjustments would be far too slow and expensive. That leaves us with the male side of the equation. Most breeding programs are already geared towards using the characteristics of the terminal sire lines to define the market hog characteristics. To incorporate meat quality traits in the breeding program, for the foreseeable future the place to do that is in the terminal sire lines.

WHAT TRAITS WILL BE IMPORTANT

One of the advantages of the initial approach of looking at traits of economic importance to the production system is the clear definition of what traits are important. By defining a production scope, the importance and relevance of traits are very clear. When defining the importance of traits closer to the consumer and further removed from the production economics, the challenge increases.

Traits with emerging importance will be more closely related to consumer product quality. Consumer preference surveys suggest appearance has a lot to do with a perception of quality that leads to a purchase decision. Preferred appearance factors differ regionally and globally. Once the product is purchased, the eating experience should live up to the perception to complete the picture (Ngapo, 2005). Appearance factors for meat include colour, marbling, lack of fat cover and lack of seepage in the package. Lack of fat cover we have already addressed with conventional selection but colour and marbling (or intramuscular fat – IMF) are more challenging. Colour and IMF can be scored visually on the loin of a hanging carcass as part of the grading process so routine measurement of these traits can be done with additional labour in the processing plant. There is, however, an additional cost because these measurements require ribbing the carcass like a beef carcass which splits the loin in two sections, something not usually done for pork. Lack of seepage in packaging is related to pH and water holding capacity both of which require analysis of a sample of muscle post-mortem which escalates the cost of measurement rapidly. Water holding capacity also has a large impact on the potential for successful further processing. Other traits may emerge in the future but the focus of new traits will be centred around the consumer and will be difficult and costly to measure on large numbers of animals.

New genetic improvement technology makes the challenge somewhat easier. In addition to traditional approaches with EBVs (See, 2005), we also have the capability to use molecular genetic markers in the selection process. Swine breeders in Ontario were world-leading adopters of marker assisted selection (MAS) technology with the malignant hypothermia or PSS gene which is now known to be the ryanodine receptor gene (*RYR1*) (O'Brien et al., 1993). The deleterious allele was very quickly eliminated from many breeders' herds through

the use of the HAL-1843™ molecular genetic test. Similar technology is being developed and will be developed for important genes influencing meat and carcass quality traits.

MAS requires a marker or difference in the DNA sequence that is identified in the lab and associated with a difference in an important trait or traits. The process of finding the association requires collecting data on a limited number of animals and matching the difference in the DNA with the difference in the trait(s). The difference in the DNA is usually not the actual sequence change that creates the difference in the trait. Instead, the difference in the DNA that we use as a marker is just a convenient handle with which to track the nearby section of DNA that contains the causative difference. An analogy is an eartag in a pig; each individual pig is very difficult to recognize just by sight but with a unique eartag, it becomes very easy to locate and track a pig we are interested in. With MAS, the opportunities open up dramatically for traits that can be the focus of genetic improvement programs. The work to develop the association between the molecular genetic markers and the meat quality traits can be done on relatively small groups of pigs and, once validated in other lines, can be used widely to make selection decisions with the need for collecting data on the carcasses. Table 1 shows a list of molecular genetic markers detected by studying specific genes with a suspected role in biochemical aspects of meat and carcass quality; what is referred to as a candidate gene approach. Table 2 shows a list of regions of the genome by chromosome that have been associated with differences in meat and carcass quality traits by scanning the genome for regions associated with various phenotypes.

Table 1. Candidate genes associated with quantitative traits in swine.

Candidate gene	Normal function	Main traits the gene is associated with	Main references
RYR1	The major Ca ²⁺ release channel	PSE pork, lean content	Estany et al., 1998; Hamilton et al., 2000
RN	Adenosine monophosphate-activated protein kinase	Muscle pH, lean content	Fernandez et al., 1992; Reinsch et al., 1998; Miller et al., 2000
Pit1	Pituitary-specific positive transcription factor	Backfat, growth	Yu et al., 1995; Brunsch et al., 2002
Obese	Leptin protein	Fat deposition, body weight	Jiang and Gibson, 1999; Kennes et al., 2001
IGF-1	Insulin-like growth factor	Daily gain	Casas-Carrillo et al., 1997
GH	Growth hormone	Fat deposition, lean percentage	Knorr et al., 1997
SLA	Major histocompatibility complex (swine lymphocyte antigen system)	Body weight, litter size	Rothschild et al., 1986; Milan et al., 1998
H-FABP	Fatty acid transport	Fat deposition, IMF	Gerbens et al., 2001
A-FABP	Fatty acid transport	Fat deposition, IMF	Gerbens et al., 2001
Myostatin	Transforming growth factor	Muscle mass	Sonstegard et al., 1998

Table 2. Growth and carcass composition Quantitative Trait Loci (QTL) detected on different swine chromosomes.

Chromosome	QTL	Main references
1	Backfat, body weight, loin eye area, leanness, daily gain, marbling score, drip loss.	Moser et al., 1998; Rohrer and Keele, 1998a, b; Paszek et al., 1999; Rohrer, 2000; Malek et al., 2001a, b.
2	Backfat, intramuscular fat content, growth rate, drip loss, water-holding capacity.	de Koning et al., 2000; Rohrer, 2000; Malek et al., 2001a, b.
3	Birth weight, number of fibres in muscle, intestinal length.	Knott et al., 1998; Milan et al., 1998; Malek et al., 2001a.
4	Backfat, abdominal fat, growth rate, meat firmness score.	Andersson et al., 1994; Rothschild et al., 1995; Knott et al., 1998; Walling et al., 1998; Knott et al., 2002.
5	Backfat, average daily gain, loin colour, loin pH	Knott et al., 1998. Malek et al., 2001a, b.
6	Backfat, intramuscular fat, daily gain, carcass length.	Moser et al., 1998; de Koning et al., 1999, 2000; Rohrer, 2000; Malek et al., 2001a, b.
7	Backfat, meat color and firmness score, average daily gain.	Rothschild et al., 1995; Rohrer and Keele, 1998a, b; Wang et al., 1998; de Koning et al., 1999; Rohrer, 2000.
8	Backfat, average daily gain, carcass weight.	Rohrer, 2000; Malek et al., 2001a, b.
9	Average daily gain, backfat.	Rohrer, 2000; Wada et al., 2000; Malek et al., 2001a, b.
10	Growth rate, tenderness and marbling score.	Knott et al., 1998; Wada et al., 2000; Malek et al., 2001a, b.
11	Carcass length, drip loss.	Malek et al., 2001a, b.
12	Early growth rate, last rib fat depth and loin colour score.	Rohrer, 2000; Malek et al., 2001a, b.
13	Backfat, carcass weight, water-holding capacity, average daily gain.	Andersson et al., 1994; Knott et al., 1998, Malek et al., 2001a, b
14	Loin eye area, backfat, ham pH, colour and percent cooking loss, tenderness score.	Rohrer and Keele, 1998a, b; Malek et al., 2001a, b.
15	Loin colour, ham and loin pH, tenderness scores.	Malek et al., 2001b.
17	Colour score, juiciness score, loin colour.	Malek et al., 2001b.
18	Average backfat, loin colour.	Malek et al., 2001a, b
X	Backfat, loin eye area, carcass length.	Rohrer and Keele, 1998a, b; Rohrer, 2000.

Tables 1 and 2 represent a shopping list of resources for MAS. The genes identified in Table 1 were found through their potential involvement in a particular biochemical pathway involved in meat quality. As a result, if the connection to a meat quality trait is significant the

application to MAS tends to be more direct. Some of these genes are already the target of MAS; *RYRI* through the HAL-1843™ test and *RN*. Both of these genes have a variant that has a detrimental effect on meat quality and as such are treated like genetic diseases where the deleterious allele is being selected out of the population. Other genes have variants (alleles) that have a beneficial effect on the trait they are associated with. In these cases the goal is to increase the frequency of the beneficial allele in the population while maintaining ongoing selection using EBVs for the traits that we continue to select for “the old fashioned way”. This can be done in a variety of ways but the most common is to combine the marker information and the EBVs in an overall index that weights each by the value the traits contribute to the carcass value (Dekkers, 1999). By adjusting the emphasis on the various components in the index, terminal sire lines can be fine tuned to emphasize specific meat quality traits. That specificity is then information that can be used by commercial producers to select replacement sire line stock to target specific carcass and meat quality traits for specific markets and grading grids.

CONCLUSIONS

The traditional methods of selecting on EBVs have produced a lean, fast growing hog that produces a reasonable quality carcass in an efficient manner. Moving forward to incorporate selection for meat quality traits will involve using new genetic improvement technology like MAS in combination with the traditional EBVs for ongoing improvement of production traits.

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HOW TO HIRE AND KEEP EMPLOYEES

Ken McEwan
Ridgetown College, University of Guelph
120 Main Street East
Ridgetown, Ontario N0P 2C0
E-mail: kmcewan@ridgetownc.uoguelph.ca

ABSTRACT

A survey of swine farm employers and employees was undertaken to better understand the issues of human resource management in the industry. It was not surprising to find out that swine farm employees want the same thing as employees in other industries – respect, to feel valued by their employer and fair rewards for work performed.

BACKGROUND

Labour Force Survey data from Statistics Canada indicate that farm workers receive lower wages than jobs in other industries that require similar skills. For example, in Ontario in 2003 construction trade helpers received \$17.26/hour compared to \$10.79/hour for general farm workers. Also, truck drivers received \$17.23/hour while farm managers received \$15.27/hour. In terms of hours worked per week, Ontario farm workers reported that they worked about 46.5 hours. This is about 5 hours more than similar jobs in other industries.

As Ontario swine farms have grown in size labour requirements have often exceeded what can be provided by family members. These farms have come to rely on hired labour to fill their human resource needs. Many farms report that it is a challenge to attract, keep and motivate employees who have many employment opportunities to choose from. Added to this is the perception that agriculture is low-paying, requires long hours of work and the working conditions may not be ideal (i.e. smell, dust, physically demanding, etc.).

RESULTS

Hours of Work and Compensation

Results from the employer survey showed that the swine farm employees worked about 45 hours per week. For general labour this is about 3 hours/week more than for jobs in other industries that require similar skills, for example construction trades helpers (Source: Statistics Canada). Not surprisingly, with respect to pay swine farm employees receive lower compensation than some other industries. General and skilled swine farm labour in particular received wages up to \$6/hr less than, for example, full-time truck drivers and construction trades helpers (Source: Statistics Canada). Cash wages ranged from \$10.93/hour for general

swine farm labour to \$18.65/hour for supervisors/managers. The biggest complaint heard from employees in the survey was regarding wages.

Table 1. Hours worked/week and compensation for swine farm labour.

	General Labour	Skilled Labour	Supervisor/Manager
Average hours worked/wk	44.8	47.0	48.2
Cash wage \$/hr	\$10.93	\$15.00	\$18.65
Additional benefits \$/hr	0.80	1.92	2.85
Total compensation \$/hr	\$11.73	\$16.92	\$21.50

Swine farm employers indicated that they provide a wide range of additional benefits. These benefits included medical or dental coverage, housing, paid utilities, use of farm vehicle, the provision of pork and so on. These benefits increased the total value of the compensation package by \$0.80/hour for general labour up to \$2.85/hour for supervisors and managers.

Job Attributes

The employees that participated in the survey were asked what attributes they look for in a job. Naturally, compensation rated the highest with 24% of responses followed by appreciation for work done and having a job that is interesting each garnering 15% of responses. Figure 1 shows the response rate distribution for job attributes that employees look for and compares the responses to what employees would like to see changed in their current jobs. Compensation was reported the most often with 22% of responses for the job attribute that employees would like to see improved in their current job. Appreciation for work done and hours worked received 14% of responses with respect to other areas where improvements could be made. Although compensation was indicated to be an attribute that employees look for in potential jobs it was also the highest ranked attribute where they would like to see improvements made in their current jobs.

Comparison by Farm Size

Using gross farm sales, farms were categorized as “large” if they had annual sales greater than \$2 million and “small” if their sales were between \$500,000 and \$2 million. Small farms reported employee turnover at 52% compared to 76% turnover on the large farms. Analysis was undertaken to find out what may cause the turnover to be lower on small farms.

As shown in Table 2, while general labourers tended to receive close to the same wage on small and large farms, skilled labour and supervisor/manager employees received higher wages on small farms. The hours of work were similar between the two farm sizes for general and skilled labour but supervisor/managers worked almost 3 hours/week less on small farms than similar employees on large farms. It is likely that the higher wages on the small farms is a factor that contributes to lower turnover on these farms.

Figure 1. Job attributes.

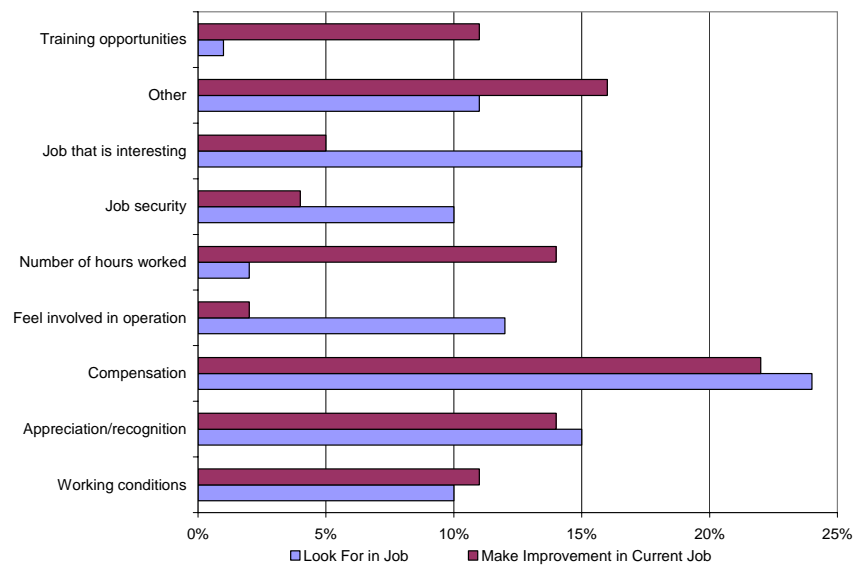


Table 2. Wages and hours per week versus farm size.

	Small Farms	Large Farms
Wages \$/hr		
General Labour	\$10.76	\$10.99
Skilled Labour	\$15.27	\$13.94
Supervisor/Manager	\$19.31	\$17.87
Hours Worked Per Week		
General Labour	44.8	45.4
Skilled Labour	47.6	47.3
Supervisor/Manager	47.0	49.8

Employee Turnover Rate

An attempt was made to analyse why employee turnover was low on some farms and high on others. An analysis of farms with low employee turnover (i.e. farms that had 0% employee turnover in the last 2 years) and farms with high employee turnover (farms with more than 70% turnover in the last 2 years) was undertaken. It was determined that the high turnover farms were more likely to give employees written job descriptions outlining duties and responsibilities and were more likely to give their employees job titles than low turnover farms. These results were surprising because it was thought that providing this information to employees would result in lower turnover.

Some key differences were noted when hours of work and compensation were compared between the low and high turnover groups. The results, displayed in Table 3, show that employees on low turnover farms received higher wages, worked slightly fewer hours, received more weekends off each month and more paid vacation days than employees with

similar skills on high turnover farms. These are thought to be important indicators of possible reasons why one group of farms experiences 0% turnover while the other group reports high turnover. The employers of the low turnover farms used word of mouth advertising to find employees and were more likely to check references than employers on high turnover farms.

Table 3. Hours of work versus turnover.

		Low Turnover	High Turnover
i) General Labour	Average hours/wk*	45.7	44.7
	# weekends off/mth	3.2	2.0
	# paid vacation days/yr	12.5	9.3
	Wages - \$/hr	\$10.10	\$10.08
ii) Skilled Labour	Average hours/wk*	44.8	51.6
	# weekends off/mth	2.2	2.1
	# paid vacation days/yr	13.5	10.1
	Wages - \$/hr	\$15.21	\$14.61
iii) Supervisor/Manager	Average hours/wk*	47.0	49.3
	# weekends off/mth	2.5	2.0
	# paid vacation days/yr	11.3	10.2
	Wages - \$/hr	\$18.25	\$16.75

*Calculated number = average # hours/day x average # days/week

Cost of Employee Turnover

Staff turnover can be costly. Survey participants assisted in determining a value for turnover. Costs related to the time for an exit interview for a departing employee and record-keeping associated with their leaving was estimated to be \$252. Replacement costs totaling \$1,138 included advertising and the salaries of individuals who discuss and interview candidates. Training costs involve manuals provided to new employees, training workshops, the salary of another employee who works with and trains the new employee and the salary of the new employee until they are fully productive. Training costs totaled \$7,018. In summary, the average total cost of turnover is \$8,408 each time an employee leaves the business. It was also reported that the average beginning salary and benefits of a new employee is \$26,653 depending on the job and it takes about 52 days for a new employee to become fully productive.

RECOMMENDATIONS

Many of the following recommendations are not unique to the swine industry. Most employees simply want to feel valued and respected for their skills and for their time working.

1. Hours of work – Indicate at the time of hire what the typical hours of work are and if flexible hours are offered.

2. Compensation – Compensation should be fair for the work done. Offering benefits such as dental and health insurance, housing, providing pork, etc. increase the total value of the compensation package.
3. Employee interaction – Let employees know when they are doing a job well and when improvements can be made. Interaction amongst employees may prove beneficial.
4. Statutory holidays and weekends – Trying to establish a mutually agreeable and acceptable schedule ahead of time shows consideration for employees. The provision of additional money or time off on another day may be incentive to work holidays/weekends.
5. Vacation time – Providing paid vacation time off is a way to reward employees for the work they have done.
6. Training – Employees who improve their skills through training will be enthusiastic about using their new talents.
7. Job Description – A written job description should outline duties to be performed, hours of work, rate of pay, additional benefits, problem solving, vacation time, how weekend and statutory holidays are provided for, training, promotion, what may cause termination, etc. This should be provided to all employees.

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EMPLOYEE RETENTION - KEEPING THE BEST

Rob McDougall
Elite Swine Inc., Cold Spring Farms
149 Brock Street
Thamesford, Ontario N0M 2M0
E-mail: Rob@coldsp.com

Direction: It is critical that everyone in your business / operation commits to a common vision / mission for your operation. This message must be consistent and understood by all members of your team.

Six Key Components: The awareness of these “six pillars” as the foundation to build upon is a must for all involved within your production system to have long term success. These are as follows: health, genetics, feed, facilities, information and people.

Critical Success Factors: The following areas are some of which we have identified as key to long term people development within our system.

1. Recruitment
 - i. Reputation of the employer.
 - ii. Involve others in the hiring process.
 - iii. Be pro – active.
 - iv. Hire the “right” person.
2. Working Conditions
 - i. Treat all with respect.
 - ii. Install a culture of continuous improvement to develop all the capabilities of all the people.
 - iii. Never request anything done that you would not do yourself.
 - iv. Coming to work needs to be “fun”.
 - v. Importance of current health and safety programs.
3. Training:
 - i. Must be practical and informative.
 - ii. Short term / long term objectives.
 - iii. Practical / Theory.
 - iv. The ability to explain why it is important.
 - v. Manage the top – they will be your long term success.
 - vi. Something that is looked forward to – want to learn about their field.
4. Communication:
 - i. The ability to keep people “cranked up”.
 - ii. Two way.
 - iii. Open and honest.

- iv. Verbal, Written, Visual.
- v. Weekly staff meetings.
- vi. Good people managers are constantly on the lookout for opportunities to talk with workers (work related & personal).

5. Attitude:

- i. Manage to the top.
- ii. Empower the people.
- iii. The ability to get the “right people on the bus”.
- iv. Verbal, Written, Visual.
- v. Good people managers are constantly on the lookout for opportunities to talk with workers (work related & personal).
- vi. Start at the top – the manager’s attitude is extremely important – cannot be going through the motions.

6. Delegation:

- i. As the barns / farms have become increasingly larger it is impossible to do everything yourself.
- ii. Key to having people involved at all levels.
- iii. Plan your Work – Work your Plan.
- iv. Delegate Jobs – Don’t Dump Them.

7. Measure & Evaluate:

- i. Involves all members of the team.
- ii. Farm performance / individual performance / COP.
- iii. Annual / Semi Annual performance reviews.
- iv. Quarterly production reviews.
- v. Monthly production reviews.
- vi. Issues and or concerns must be documented and a course of action developed.

8. Promote from Within:

- i. Shows a commitment to your staff.
- ii. Known quality.
- iii. Planned development program.
- iv. Management has a plan.

9. Remuneration:

- i. Fair and reasonable pay scale within your sector. Do your own compensation survey through industry contacts, benchmarking surveys, etc.
- ii. A consistent and planned remuneration increase program that is based on responsibility and performance.
- iii. A bonus program that encourages improvement and rewards individuals (teams) for top performance.

10. Employee Recognition:

- i. A thank you.
- ii. Quarterly Awards.
 - a. Breeding Technician Award.
 - b. Farrowing Technician Award.
 - c. Extra Effort.
- iii. Annual Awards.
 - a. Top Performing Farm.
 - b. Most Improved Farm.
 - c. Breeding Technician Award.
 - d. Farrowing Technician Award.
 - e. Extra Effort Award.
 - f. Good Neighbour Award.
- iv. Special Events.

11. Involvement:

- i. Encourage involvement in related courses, seminars, tradeshow, industry contacts, magazines, newsletters, industry functions, etc.

REPRODUCTIVE INNOVATIONS: CONTROL OF SOW ESTRUS AND BREEDING

Roy Kirkwood
Department of Large Animal Clinical Sciences
Michigan State University
Lansing, Michigan 48824-1314
E-mail: kirkwood@cvm.msu.edu

ABSTRACT

The increasing successful use of artificial insemination is facilitated by a greater knowledge of the biology of the sow during her estrous period. The realization of the importance of establishing an adequate sperm reservoir in the oviduct at an appropriate time relative to ovulation has led to advances in the management of artificial insemination. In particular, knowledge of when a sow is likely to ovulate during a natural or induced estrous period, and mechanisms influencing sperm transport have been valuable. The future of artificial insemination will likely involve a single semen dose having a reduced sperm number. This will be made possible by knowledge of the effect of site of sperm deposition on sow fertility.

INTRODUCTION

The basic principle of artificial insemination is simple; place enough viable sperm in the right place at the right time, and keep it clean. However, reproductive performance of females bred by AI is often poorer than that achievable with natural breeding. There are several reasons that sows may perform relatively poorly following artificial insemination. Using current insemination technology, 3×10^9 sperm in 80 to 100 ml extender are deposited in the cervix. This large number is necessary because most of the sperm will be lost due to back-flow of semen, as well as entrapment and death in the cervix and uterus. However, the use of new catheters designed to allow trans-cervical/uterine deposition of sperm will reduce semen backflow. Further, by limiting sperm losses, the number of sperm in the original semen dose can be reduced.

The ultimate objective of AI is to ensure a sufficient number of sperm are in the first part of the oviduct (the sperm reservoir) at the time of ovulation. If time of ovulation is not known, then multiple inseminations are required. However, if time of ovulation can be reliably predicted, then a single insemination should suffice. This paper will focus on technologies available to achieve the objective of good fertility following a single insemination of fewer sperm.

CONTROL OF ESTRUS

Estrus Stimulation

In sows, wean-to-estrus intervals greater than 5-days are associated with reduced farrowing rates and litter sizes (Wilson and Dewey, 1993; Steverink et. al., 1999). The reason for this is unclear but may involve poor synchrony between time of ovulation and time of breeding because these sows are more likely to be early ovulators (see below). As such, and especially associated with once daily estrus detection, it is probable that many of these sows will have already ovulated when estrus is detected. In consequence, this sub-population of sows will be subject to post-ovulatory inseminations, which are associated with poorer fertility and potentially uterine infection (Rozeboom et al., 1997; Tarocco and Kirkwood, 2001). Therefore, when records indicate a higher likelihood of delayed estrus (eg. seasonal or associated with primiparous sows) gonadotrophins (PG600 or Pregnenol) can be used to induce a more prompt return to estrus (Kirkwood, 1999). These hormone preparations are effective for inducing shorter wean-to-estrus intervals and therefore will create a population of sows that will be late ovulators. If the breeding SOP calls for insemination at estrus detection and 24 hours later, then many of these sows will have intervals from last insemination to ovulation of >24 hours (Table 1), which may reduce fertility. Therefore, when estrus is hormonally induced, be prepared to modify breeding management to include a day-3 insemination.

Table 1. Effect of PG600 on wean-to-estrus (WEI) and estrus-to-ovulation (EOI) intervals.

Control			PG600	
WEI	No. sows	EOI	No. sows	EOI
<4 days	4	45.0	20	57.6
4 days	13	46.9	35	47.3
5-6 days	34	39.3	13	32.0

Knox et. al., 2001

Estrus Synchronisation

The feeding of Regumate is an effective means of controlling estrus in gilts and sows (eg. Foxcroft et. al., 1998). Ideally, the animals should be individually fed so that they consume at least 15 mg/d (but preferably 20 mg/d). While there is likely no problem with overdosing (except economic), underdosing Regumate (<13 mg/d) has been shown to be associated with cystic follicles in gilts (Davis et. al., 1979; Kraeling et. al., 1981). However, if fed appropriately expect 85 to 95% of sows to exhibit estrus on days 4 to 8 after last feeding.

Note that the first Regumate feeding must be on the day of weaning, **not** the day after weaning. Feeding of Regumate for 7-days from weaning improved litter size of primiparous sows (Kirkwood et. al., 1986). Presumably, the feeding of Regumate captured the effect of skip-a-heat breeding but with fewer non-productive sow days (Table 2). Further, early

weaning is associated with reduced sow fertility but, when 12-day weaned sows were fed Regumate to delay estrus for an additional 12 days, fertility was improved (Table 3).

Table 2. Effect of 10-d of Regumate or skip-a-heat breeding on fertility of primiparous sows.

	Control	Ship-a-heat	Regumate
Farrowing rate, %	74.8	87.2	89.5
Next litter size	8.7	11.2	10.2

Morrow et. al., 1989

Table 3. Effect of a Regumate on fertility of early weaned sows.

	12-d, Regumate	12-d, control	24-d, control
Interval to estrus, d	6.2	7.3	5.6
Estrus by 7-d, %	97	64	87
No. corpora lutea	16.9	15.4	14.9
Embryo survival, %	77	68	68
No. embryos	13.0	10.5	10.1

Koutsotheodorus et. al., 1998

The duration of Regumate feeding does not appear to be critical. Feeding for 7-days has the advantage of simply shifting sows from one breeding week to the next. However, there is some evidence that sows will benefit from feeding Regumate for as little 3-days from weaning (Table 4).

Table 4. Effect of short-term feeding of Regumate on fertility of primiparous sows.

	Control	Regumate 0-3 days	Regumate 2-7 days
No. sows ¹	201	202	207
Farrowing rate, % ¹	76.1	82.2	71.5
Litter size ¹	9.8	10.1	10.4
No. corpora lutea ²	17.2	17.9	16.6
Ovaries: only CL ²	60	78	46
4-cell embryos, % ²	61	97	67

¹Forgerity et. al., 1995; ²Martinat-Botte et. al., 1995

BREEDING MANAGEMENT

The basic principles of artificial insemination are simple; deposit enough viable sperm in the right place at the right time, and keep it clean. Using current insemination technology, 3×10^9 sperm are deposited in the cervix. This large number is necessary because most of the sperm will either be lost due to back-flow of semen, as well as entrapment and death in the cervix and uterus (Steverink et. al., 1998). When fewer sperm were deposited and semen backflow

was considered excessive during the insemination, sow fertility was reduced. If backflow is excessive, insufficient sperm will remain in the sow, fertilization rate will be compromised, and an increased regular return rate will be observed.

In reality, it is not the number of sperm deposited in the cervix or uterus that ultimately controls fertility, it is the number of sperm in the oviduct at the time of ovulation that is important. The proportion of inseminated sperm that actually get to the oviduct is variable, but <2% is a reasonable figure. The sperm in the oviduct enter an arrested state and constitute the sperm reservoir potentially available to fertilise ova, being released in the peri-ovulatory period. The number of functional sperm available for fertilisation will impact sow fertility and depends on the number originally entering the sperm reservoir and the interval between sperm entry to the reservoir and their redistribution at the time ovulation; the latter being influenced by timing of insemination relative to ovulation. Taking the above into consideration, objectives for successful AI will include ensuring an adequate number of sperm reach the sperm reservoir, and depositing the sperm at an appropriate time relative to ovulation.

EFFECT OF TRANSCERVICAL INSEMINATION

It is known that progressively fewer sperm need to be inseminated the closer to the uterotubal junction that they are deposited. Recently, insemination catheters that allow semen deposition into the body of the uterus, or into the proximal uterine horn, have become available. When deposited near the uterotubal junction using either surgical (Krueger and Rath, 2000) or endoscopic techniques (Martinez et. al., 2001a) extremely low numbers of sperm (10×10^6) are required. At this time these strategies would only be justified if dealing with semen of extremely high genetic value, or for sex pre-selected semen. Very recently, a new catheter has been designed that allows entry into a uterine horn to within 25 cm of the uterotubal junction (deep intrauterine insemination). Acceptable fertility was seen with insemination of 50 to 150×10^6 sperm (Martinez et. al., 2001b; Roca et. al., 2003). This catheter remains to be commercially exploited but several companies have developed other AI catheters that are capable of being passed via manual manipulation through the cervix of the sow to allow deposition of the semen dose into the uterine body (transcervical or uterine insemination). These latter catheters are composed of a regular cervical catheter and a longer, smaller diameter, flexible inner catheter that is advanced through the cervix to the uterine body. When used, the cervical catheter should be inserted and left for a couple of minutes to allow the cervix to relax before advancing the inner catheter. As a viable option, this technique does allow sperm numbers to be reduced to 1×10^9 per insemination dose (Watson and Behan, 2002). Field trials have confirmed that farrowing rates and litter sizes statistically comparable to standard AI can be maintained with reduced sperm numbers using this technique (Table 5), although there is occasionally some suggestion of a reduction in litter size. It is likely that the timing of insemination relative to ovulation becomes progressively more important as the number of sperm deposited is reduced (Rozeboom et. al., 2004).

Timing of Insemination

It is accepted that sows having a short wean-to-estrus interval will tend to exhibit a longer duration of estrus and conversely, sows having a long wean-to-estrus interval will tend to have a short duration of estrus. Further, ovulation is believed to occur at about 70% through estrus, independent of the duration of estrus. The effect of this is that sows having a short wean-to-estrus interval (eg. 4 days) will tend to be late ovulators while sows having a long (eg. >5 days) wean-to-estrus interval will tend to be early ovulators (Table 6).

Table 5. Effect of sperm dose and site of deposition on sow fertility.

Site of deposition	Sperm dose (x10 ⁹)	Farrowing rate, %	Litter size
Cervix	1	65.8	10.3
	2	91.8	12.6
	3	91.1	12.5
Uterine body	1	86.9	12.1
	2	92.5	12.3
	3	90.5	12.3

Watson and Behan 2002.

Table 6. Effect of wean-to-estrus interval (WEI) on estrus-to-ovulation interval.

Interval to ovulation	4-d WEI	5-d WEI	6-d WEI
0-24 h	5%	16%	45%
24-32 h	19%	36%	17%
32-40 h	34%	25%	18%
>40 h	42%	23%	9%

Kemp and Soede, 1996.

Sow fertility following AI depends on the time of insemination relative to ovulation (Kemp and Soede, 1996). To maximise fertility, deposition of fresh-extended semen into the sow should occur during the 24-hours before ovulation. However, if the semen is relatively old, or the number of sperm inseminated is relatively low, then the high fertility window for insemination may be only 12 hours (Waberski et. al., 1994).

The most common protocol for the induction of estrus in weaned sows is the injection of 500 to 750 IU of eCG (e.g. Pregnenol) or a combination of 400 IU eCG and 200 IU of hCG (PG600). There is a wealth of literature demonstrating the efficacy of this approach for induction of a fertile estrus after weaning but while efficacious for induction of estrus, injection of eCG or PG600 will not provide adequate synchronization of ovulation. Further, by inducing an earlier onset of estrus with either eCG or PG600, the EOI may increase, making the prediction of time of ovulation even more difficult. However, because gonadotropin treatment results in a sow population having longer estrus-ovulation intervals, this knowledge can be used in a protocol of induced ovulation to allow a more precise timing of insemination relative to ovulation.

It is known that ovulation typically occurs at about 42 hours after hCG injection. When ovulation is induced using porcine luteinizing hormone (pLH), the interval from injection to ovulation is shorter, at 36 to 38 hours (Cassar et. al., 2005). Therefore, if sows are expected to ovulate at >36 hours after estrus detection, induction of ovulation using pLH (Lutropin) will provide for a relatively predictable time of ovulation. Since the target is to inseminate sows during the 24-hour period before ovulation, if time of ovulation can be accurately predicted, then breeding management for optimal sow fertility will be relatively simple. Indeed, when time of ovulation can be accurately predicted, a single insemination resulted in sow fertility comparable to that following two inseminations (Table 7).

Table 7. Sow fertility to single or double insemination at an estrus induced by eCG with or without induction of ovulation by pLH.

Variable	Control	eCG	eCG+LH	eCG+LH*
No. sows	119	103	103	102
Farrowing rate, %	68.7	69.0	84.2 ^c	86.1 ^c
Litter size	11.1 ± 2.6	10.7 ± 3.2	10.3 ± 3.1	10.6 ± 3.5

eCG+LH*, sows received single insemination 40 hours after LH injection

CONCLUSIONS

The future of artificial insemination of swine will involve a single insemination of fewer sperm. To achieve this, some measure of control of time of ovulation will be used to permit improved timing of insemination. In association with transcervical insemination, improved timing relative to ovulation may facilitate the commercial uptake of insemination of frozen-thawed sperm and, potentially, sex-sorted sperm.

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REPRODUCTIVE INNOVATIONS FOR SWINE PRODUCTION: FUTURE IMPACTS OF GENDER PRE-SELECTION, EMBRYO TRANSFER AND CLONING

**Mark Wilson
Minitube of America, Inc.
P.O. Box 930187, Verona, WI 53593
E-mail: mewilson@minitube.com**

ABSTRACT

It is estimated that in the past five years, flow cytometric sorting of gender pre-selected sperm using DNA as the marker has produced over 30,000 offspring. The majority of these offspring were cattle for two reasons: 1) The cattle industry has accepted the use of gender specific sperm for commercial reproduction and 2) Cattle have a distinct advantage over swine in requiring a significantly lower number of spermatozoa for fertilization. In the swine industry, using gender pre-selected sperm has not progressed at the same pace. Nevertheless, the ability to pre select gender of the offspring in the pig is one of the most sought after reproductive innovations because it would have a huge economic impact on pork production by reducing animal maintenance costs and supporting production goals. However, the current methods for producing gender pre-selected sperm and then delivery to the uterus require development to make them more productive, efficient and cost effective in swine production.

While porcine embryo transfer (ET) has been practiced for about 50 years in a research setting, it has been employed more recently to salvage a specific genotype from a disease scenario or for international transfer of valuable genetics. While ET is a practical application for modern genetic propagation, it has not received wide acceptance as a method of choice for reproduction because it requires skillful surgical embryo recovery and transfer. Further development of embryo recovery technique and non-surgical embryo transfer will lower the cost of ET and make the technology more user friendly in swine production.

While one considered the future of animal reproduction, cloning (-via embryo splitting-) and nuclear transfer (embryo from somatic cell DNA) are now the reality of today. When the lamb “Dolly”, was born in 1996 as the first domestic animal cloned from an adult animal somatic cell, the fascination and fervor for the potential benefits resulting from the cloning process were launched. Since then, nuclear transfer has been successfully used to produce clones in many different species. Cloning technology will not replace traditional population genetic approaches to swine reproduction but will augment the potential to further genetic progress, increase production efficiency and improve protein quality for consumers throughout the world.

GENDER PRE-SELECTION

Physical Cell Sorting

The ability to pre-select gender of potential offspring has huge economic implications in the swine industry. Many attempts have been made to separate X and Y sperm in the past 70 years. Mechanical methods and physical differences between X and Y sperm have been relatively ineffective in obtaining a higher proportion of either sex in sperm sex ratio or offspring. Current research efforts are attempting to develop mass sorting techniques based on markers or chromosome specific proteins on the surface membranes of the X and Y sperm. Using 2D electrophoresis, over 1000 proteins have been isolated and characterized on the surface of sperm cells with no differences found between X or Y sperm (Hendriksen et al., 1996; Johnson and Clarke, 1988). This method of sorting sperm from a specific protein on the sperm surface has no published scientific evidence as a viable option to semen sorting at this time.

Sorting Living X and Y Sperm Based on DNA

With the improvement of staining methods and techniques and the understanding of the orientation of the sperm cell in flow cytometric sorting, relatively small differences in staining intensity between X and Y sperm can be detected and sorted (Johnson and Pinkel, 1986). Improved use of fluorochromes and utilization of vital stains to label the DNA of living sperm cells led to the sorting of X and Y bearing sperm and the Beltsville Sperm Sexing Technology (Johnson et al., 1987a). More recently, this technology has been improved with the use of the MoFlo high speed sorter after several modifications (Johnson et al., 1987b; Johnson and Clarke, 1988). There are now several other high speed sorters on the market today.

The effectiveness of this system has been validated by flow-cytometric re-analysis of sorted sperm cells (Johnson et al., 1987a), fluorescence in situ hybridization (FISH) procedures (Kawarasaki et al., 1998) counting the microsatellite DNA probe on the Y sperm, and by PCR (Welch et al., 1995). All methods have verified with good accuracy that the Beltsville Sperm Sexing Technology is consistent and repeatable for altering the sex ratio of offspring in livestock. Besides laboratory validation, gender pre-selected sperm cells were used in combination with in vitro fertilization of in vivo matured oocytes. Cleavage rates after IVF were 56% of the embryos. The viable 2-4 cell embryos were surgically transferred to asynchronous gilts (n=4) with two pregnancies resulting (Rath et al., 1997). The litters from these two pregnancies were 6 and 4 pigs and all piglets were females. Further studies conducted at Beltsville produced offspring in 9 litters. The control litters gave a sex ratio of 52% male and 48% female offspring while the 6 litters with sexed IVF embryos gave 97% females pigs (Rath et al., 1999). Another study showing the effectiveness of the orientating nozzle of the high speed sorter used semen selected for both the X and Y in the IVF program. Five litters were born with 97% females from the X sorted sperm and three litters from the Y sorted sperm where 100% were males (Abeydeera et al., 1998). Researchers found that sperm must be used rather quickly after cell sorting and polyspermy is common, particularly in swine. Pigs have recently been produced using intracytoplasmic sperm injection (ICSI) from cytometrically sorted boar semen (Probst and Rath, 2003). The ICSI technique greatly

extends the use of sorted porcine sperm cells as it only takes one sperm per oocyte. While the use of these assisted reproductive technologies enables the use of gender pre-selected sperm in swine production, these approaches are impractical for everyday use.

Insemination of Flow Cytometric Sorted Semen

Surgical intratubal inseminations are effective for producing offspring from gender pre-selected sperm (Johnson, 1991), and pregnancies have also resulted from deep intra-uterine horn inseminations with gender pre-selected semen (Rath et al., 2003; Vasquez et al., 2003). The use of traditional artificial insemination in pigs using gender pre-selected sperm is not practical at this time because of the large number of sperm cells needed for insemination and the inability of techniques to sort the large number of sperm cells required.

New Technology in Gender Pre-Selection

Monsanto® recently announced a new machine designed to sort cattle sperm cells. It significantly speeds up cell sorting under lower pressure and reads by laser from multiple angles causing fewer traumas to the sperm. A sorter of this speed and detection technology has not been developed for swine.

Current research efforts are attempting to develop mass sorting techniques based on markers of chromosome specific loci on the X and Y chromosomes.

EMBRYO TRANSFER

The swine industry has become increasingly more aware of embryo transfer (ET) as a means of reproduction to reduce the risk of disease as new genetics are introduced for herd replacement and genetic progress (Holtz et al., 1987). The first documented surgical embryo transfer in swine appeared in 1951 (Kvasnicki, 1951). It was not until the late '60s that the first pregnancy resulting from non-surgical embryo transfer in a pig (Polge and Day, 1968) was reported.

Surgical Embryo Transfer

The widespread acceptance and use of ET in the swine industry is so far limited because surgical methods are required to recover and transfer embryos. These procedures make it difficult to coordinate sterile or semi-clean surgical locations and arrange transportation of embryos. Embryos are perishable and easily lost if the plane is delayed or papers are not in order. The factors that affect the success rate of surgical ET in the pig are different than cattle because of the high fecundity rate in pigs. Surgical ET and even non-surgical ET in swine are impacted by several factors such as; 1) selection and stimulation of the donor sow, 2) recovery of embryos, 3) embryo handling, including embryo assessment, transportation, medias, and storage, 4) selection and synchronization of the recipient sow and 5) transfer of recovered and washed embryos. A number of documented results for surgical embryo transfer are listed in the Table 1 below (Brüssow et al., 2000)

Table 1. Results of embryo transfer following surgical embryo transfer.*

No of transfers (n)	Pregnancy Rate (%)	Litter size (mean)	References
27	70	5.7	Dziuk et al., 1964
77	73	6.2	Schlieper, 1983
46	68	6.7	Kruff, 1985
206	53	7.0	Holtz, 1988
39	80	8.1	Cameron et al., 1989
112	63	7.7	Brüssow, 1990

* Table modified from Brüssow et al., 2000.

Commercial applications and use of surgical embryo transfer have some of their own trade secrets and report slightly higher efficiencies of reproductive success. Still, for ET to gain wide spread appeal in the swine industry and to move genetic material, the goal needs to reduce the need to use surgery for collection and transfer of the embryos.

Non-surgical Embryo Transfer

Although, it was demonstrated in the late 60's that embryos from the pig could be transferred non-surgically, greater efforts toward this goal were further demonstrated in the 90's. The later technique showed that deposition of embryos into the body of the uterus or in the caudal end of the horn could be done with no anesthesia and produce farrowing rates up to 40% with 5-7 piglets born (Hazeleger and Kemp, 1994; Galvin et al., 1994; Hazeleger et al., 2000). These successes still leave room for improvement in reproductive performance before invoking the confidence of the pork producer or genetic company to use this as a technique to transfer genetic material. Data from surgical ET would suggest that the uterine body might not be the best location for deposition of embryos and that a site much further up toward the cranial end of the uterine horns might improve both farrowing rate and litter size (Stein-Stefani et al., 1987; Wallenhorst and Holtz, 1999). This data showed a pregnancy rate of 12% in the body of the uterus, 81% for the caudal end of the horn and 88% for the middle of the uterine horn. Survival rate of these embryos at day 28-34 was only 3% at the uterine body, 29% at the caudal end of the uterine horn and 41% at the middle of the horn. It is not known whether placement of the embryos affects survival with nonsurgical ET.

This data suggests that a nonsurgical ET method in swine with embryo deposition further up into the uterine horn would likely be a benefit to reproductive success. In one procedure, a modified flexible catheter (43 cm in length) is inserted through a traditional artificial insemination Spirette. The Spirette is inserted into the cervix of a non-sedated sow. The inner catheter is guided up into one of the uterine horns and 24-31 embryos are deposited. The average insertion of the catheter takes about 2.5 minutes. A study conducted with this method of nonsurgical ET reported 70.8% farrowing rate with an average litter size of 6.9 pigs on 17 females (Martinez et al., 2004). Table 2 shows some results of non-surgical transfer.

Table 2. Results of embryo transfer following non-surgical embryo application.*

No. of Transfers (n)	Pregnancy rates (%)	Litter size (mean)	References
58	9	5.2	Reichenbach et al., 1993
21	33	6.7	Hazeleger and Kemp, 1994
46	22	4.3	Galvin et al., 1994
16	31	6.2	Li et al., 1996
25	64	3.1	Yonemura et al., 1996
27	59	10.9	Hazeleger and Kemp, 1999
24	70.8	6.9	Martinez et al., 2004
19	53	6.9	Dyck et al., 2005

* Table modified from Brüssow et al., 2000.

This nonsurgical method is relatively simple to use but requires on-farm training to become proficient at the insertion of the inner catheter. This method provides the beginning of a simple and practical method to perform non-surgical embryo transfer.

Additionally, new technologies such as cryopreservation of porcine embryos can add practicalities of storage and shipment of embryos (Dobrinisky 1997; Dobrinisky et al., 2000).

CLONING

Brief History of Cloning

1984 – Danish scientist, made a genetic copy of a lamb from early sheep embryo cells (Willadsen, 1986). This technique, eventually called “twinning”, led many other scientists to follow with production of “twin” cattle, pigs, goats, rabbits, and rhesus monkeys.

1993 - Creation of calves by transferring the nuclei from cultured embryonic cells (Simms and First, 1994)

1995 – Differentiated embryo cells to clone two sheep. (Campbell et al., 1996)

1996 – Dolly, the first mammal to be cloned from adult cells. (Wilmut et al., 1997)

2000 – First pigs are cloned. (Betthauser et al., 2000, and Polejaeva et al., 2000)

Principles of Cloning

The foundation for cloning is an embryology program with controlled testing of media, oocyte maturation and blastocyst development rates, IVF success, and equipment for manipulation of oocytes and donor cells. When excellent blastocyst formation is accomplished with oocytes extracted from ovaries collected from females slaughtered in an abattoir, then the lab is ready to try its hand at producing clones. Therefore, the first and most important component of a successful cloning program is an outstanding in vitro embryo production lab.

All organisms are influenced by the interaction of genes with their environment. This is sometimes referred to as epigenetic effects. The impact of the environmental influences may

cause clones to differ phenotypically; however, they will still have the same genetic information.

Factors which Impact Cloning:

1. Source and quality of the oocytes. Seasonal variation in the quality of oocytes can be significant.
2. Culture media, laboratory cleanliness and technique.
3. Timing of the different processes is critical to success.
4. Recipient management- sows versus gilts, time of the year, natural timing of estrus versus hormonally synchronized timing. Whether the sows are from maternal lines or paternal lines will have a significant impact on results.
5. Different cell culture lines can have differing results in cloning. (Forsberg et al., 2002)

Success rates for reconstructed embryos leading to live births remain relatively low. Most losses occur in early development (first trimester), however, cloned animals also die in late pregnancy or soon after birth, often due to respiratory and physiological dysfunction. Increased abnormal placental development, increased fetal losses, large offspring syndrome in cattle and sheep, and a generally higher incidence of abnormalities have all been observed. However, research suggests that both cloned animals and their offspring are safe for milk and meat production and consumption. Several countries such as Denmark, Japan and Germany have passed legislation that allows the introduction of cloned offspring into the food chain. It is anticipated that the US will soon release a study that will also provide evidence that food from offspring of clones is safe for the food chain. A recent survey conducted by KRC research and released November 4, 2005 reported that two thirds of US consumers would either buy or consider buying meat and milk made from clones.

How to Clone From Adult Cells

Somatic cell chromatin transfer is the process of making a genetic copy of a desired animal that will carry the genetic material from the source animal. This process differentiates itself from blastomere separation or blastocyst division, which produces clones of the embryo (a genetic combination of both parents). The chromatin transfer technique has the advantage of allowing for the selection and multiplication of the adult traits that one desires. The following steps outline somatic cell chromatin transfer, a technology licensed from Hematech® by Minitube of America.

Oocyte Aspiration

Ovaries are typically purchased from packing plants and brought back to the embryology lab according to strict bio-security measures. Oocytes surrounded by the cumulus cells or cumulus-oocyte complexes (COCs) are aspirated from properly sized follicles on the ovaries to obtain the ideal stage of a pre-ovulatory follicle. The oocytes are placed in maturation media and mature in vitro. Each oocyte goes through meiosis to yield a metaphase II oocyte and a polar body that passes out of the oocyte to a location under the zona pellucida.

In-vivo Derived Oocytes

Oocytes may be collected from a given population of sows, synchronized for ovulation, to select the proper timing to flush the in-vivo matured oocytes. Oocytes from a known source and status of the sow will usually give an advantage in cloning success rates and may be preferred by customers in the cloning of their own animals.

Enucleation

Mature oocytes of normal morphology are selected for enucleation (DNA removal). Their chromosomes are stained to be visible in florescent light under inverted microscopes fitted with hydraulically-controlled micromanipulators. These micromanipulators allow the technician to hold and manipulate the oocyte while locating the polar body and removing the chromosomes. Identifying the polar body location helps the technician to identify the location of the chromosomes lying in the cytoplasm of the oocyte. With smooth precision, the technician inserts a glass needle under the zona pellucida of the oocyte and removes a karyoplast containing the polar body and chromosomes from the oocyte. Remaining is an enucleated egg that is a cytoplasm devoid of chromatin material.

Chromatin Transfer

The next step is to isolate the cultured adult somatic cells and place one of these cells under the zona pellucida of the cytoplasm. It is important to insert the cell through the opening made when enucleating the egg in order to prevent any further damage to the zona pellucida. Once the donor cell is placed under the zona pellucida the donor cell is electrically fused with the enucleated oocyte.

Fusion

To fuse the donor cell nucleus into the oocyte, the cell membrane must be in direct contact with the oocyte cytoplasm. Fusion is accomplished with an electrical pulse generated by a special device that causes the donor cell to fuse with the oocyte. A few hours after fusion, the reconstructed cloned embryos are activated to trigger a response like fertilization. If all works well, the somatic cell chromatin material now inside the cell is reprogrammed and acts as a fertilized embryo to begin development.

Embryo Transfer

In pigs, approximately 100+ reconstructed embryos are surgically transferred into the oviducts of a synchronized recipient. About 50% of the females become pregnant and of these, about 70-80% farrow. Therefore, roughly 30% of the sows surgically implanted will give birth to cloned piglets. Generally, cloned embryos will have gestation length a few days longer than normal (117-118 days).

Uses for Cloning

The application of cloning technology is an excellent way to replicate valuable animals for widespread dissemination of desirable traits. The greatest potential impact for the swine industry will be the replication of genetically superior boars for placement in boar studs for distribution of their genetically superior semen. This application of cloning simply multiplies “normal” top genetic animals to be used by the swine industry for the efficient and increased production of meat protein to feed the world. Anticipated goals for the swine industry include improved rates of weight gain, feed conversion and reduced product variation. Gene marker technologies may be used to identify animals with a particular disease resistance. These animals can be cloned and used for breeding to produce disease-resistant progeny resulting in protecting the swine industry from annual losses of billions of dollars.

Clones may also be used to reduce variation in experimental models, thereby reducing the number of experimental animals needed to realize statistical significance in each experiment. The far reaching impact of using cloned animals as experimental models accelerates the output of scientific information for use by the swine industry. Cloning will also be used to help maintain or expand populations that are nearing extinction. There are even suggestions to bring back populations of animals that are already extinct. This, however, would not be possible unless a preserved source of unbroken or uncorrupted DNA and a source of oocytes from a closely related species to allow embryonic development in the surrogate recipient mother are available.

Other applications of cloning will result from well-established methods to genetically modify cells before their use in cloning procedures. The ability to make changes in the genome of animals will enable strategies to directly add desirable traits and remove undesirable traits. Envisioned agricultural applications include safer, healthier and more economically priced food products with reduced environmental impact.

Health-care applications of genetically modified cloned animals include the production of therapeutic proteins in the milk or blood of animals (see GTC Biotherapeutics at www.transgenics.com and Hematech at www.hematech.com); the use of genetically modified animals for xenotransplantation; and the development genetically modified animal models for human diseases (Kolber-Simonds et al., 2004).

CONCLUSIONS

At the present time, gender pre-selection in the pig has only been accomplished using the Beltsville Sperm Sexing Technology. Currently, the slow sorting speed of the flow cytometers limits most of the use of gender pre-selected porcine semen to technologies such as deep intra-uterine inseminations with low sperm numbers, ICSI, and IVF fertilization of oocytes. As technologies advance in the equipment and in new sorting techniques for DNA staining, using gender pre-selected semen will become a reality in pork production.

Interest will increase in the movement of genetics between farms and countries because of the reduced risk of disease through technologies such as embryo transfer. Currently, most ET is done surgically. Development of nonsurgical ET techniques that will be adaptable for farms will increase and make the use of ET technology more widespread. New catheter developments have greatly improved the results of non-surgical ET; however the industry has a long way to go to perfect non-surgical flushing of embryos in the pig.

The success of research groups to successfully produce cloned pigs has resulted in the recognition of cloning and its role in agriculture. Several countries have now passed legislation to accept offspring of clones for use in their food chains. Successful clones are reliant on excellent embryology and embryo transfer programs where manipulation of the embryo does not decrease the survival rate and efficiency of producing offspring. To cloning animals found with genetic markers for disease resistance and extremes on production parameters such as feed efficiency, rate of gain will pay large economic dividends for the swine industry.

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UNDERSTANDING THE SPREAD OF PRRS BETWEEN HERDS

Cate Dewey
Department of Population Medicine
University of Guelph
Guelph, Ontario Canada N1G 2W1
E-mail: cdewey@uoguelph.ca

ABSTRACT

If we are to understand the spread of the PRRS virus among herds in Ontario, we will have to have a large proportion of Ontario swine herds participate in the study that is currently occurring in Ontario. Major factors associated with the spread of this disease will be missed if only a small segment of the Ontario industry participates. Herds that are PRRS virus negative are equally important- otherwise the researchers may incorrectly identify factors common to negative and positive herds. Results of this research will assist with the prevention of PRRS virus infections in the future. The purpose of this paper is to describe the objectives of the PRRS mapping project and to encourage swine producers in Ontario to participate. Information collected from participating producers will be kept confidential. Each barn will be given a unique identification number so that persons working with the data will not know the name of the producer or the name of the farm. A summary of the data collected from this project will provide the backbone of the oral presentation.

PRRS VIRUS MAPPING PROJECT

Purpose of the Research

The main objective of the PRRS virus mapping project is to determine how the PRRS virus is spreading among farms in Ontario. We will identify the various PRRSV strains in Ontario as measured by the gene sequences and create a system to track the movement of the virus between herds. Once we understand how the virus is moving between herds, we will be able to recommend ways producers can prevent, control and ultimately eliminate this disease from their herds.

Current Status of the Research

The PRRS mapping project is well on its way. We have a team of committed researchers working on the project including Dr. Beth Young and Dr. Zvonimir Poljak, Karen Richardson and Thomas Rosendal and myself. Dr. Susy Carman and her team of technicians in the Animal Health Laboratory (AHL) are doing the PCR and gene sequencing analyses. Dr. Beverley McEwen, also from the AHL, has also helped with the project. As of the beginning of March we have 63 producers who have committed to participate in the project by signing the permission forms. The permission forms enable the researchers to have access to the test results from the AHL and the GPS location information from Ontario Pork. Producers are also

asked to give the researchers permission to ask the private veterinary practitioners for clinical disease information to validate survey data but this is unlikely to be used.

To date (March 1st, 2006), there are 38 producers who have completed the questionnaire describing their herd and the movement of pigs, people and supplies in and out of their farms. Of the 38, there are 8 control herds and 30 case herds. There are 6 herds that had PRRS sequences done prior to January 15, 12 cases that had positive PCR tests prior to January 15 but no sequences completed and finally 12 cases that were new cases after January 15.

We will be using the GPS location information from Ontario Pork to map the PRRS positive (case herds) and PRRS negative (control herds). If the barn does not have a GPS location, we can include the barn using the fire number and name of the road and township.

How Do You Participate in the Study?

Contact Dr. Beth Young or Karen Richardson at the University of Guelph
FAX: 519-763-3117
Phone: 519-824-4120 ext 45009 (Karen) or ext 54873 (Beth)
Email: krichard@uoguelph.ca or byoung@uoguelph.ca

Beth will send you a letter describing the project and a permission form for your signature and contact information. Return the permission form to Beth.

Beth will send you a questionnaire that you can complete and then send back to her by mail or she will telephone you to complete the questionnaire. It will take 15 minutes of your time to complete the questionnaire by telephone. If the PRRS virus from your herd has not been sequenced, the project funds will pay for that analysis provided it has been at least one month since the previous sequence was done.

Who Should Participate?

PRRS virus negative herds

We need to have Control Herds – if you have a PRRS virus negative herd we need you to participate. Without control herds, we will not be able to determine how the PRRS virus is spread from farm to farm in Ontario. Owners or managers of control herds will be asked to complete a survey and tell the researchers how they know their farm is negative. (perhaps diagnostic tests have been done and/or there have been no clinical signs of PRRS virus problems).

PRRS virus positive herds

We need all (or most) of the PRRS positive farms in Ontario – it is important that we do not miss PRRS positive farms. Firstly, because we need to describe the variety of types of PRRS viruses in Ontario. Secondly, because we need to see where the links are between these types

of PRRS virus. How common is each type? How does each type spread from one farm to another? What clinical signs are seen with each type?

If you have already had a positive PRRS virus PCR test and gene sequencing done on your herd, we need your permission to use your information. Then you will be asked to complete a survey. The survey can be completed by mail or Beth Young will telephone you to obtain the answers. This will take 15 minutes on the telephone.

If you have already had a positive PRRS virus PCR test but have not had gene sequencing done – we still need you to participate. We will pay to have the gene sequencing done on the virus sample that is in the freezer at the Animal Health Laboratory. To participate, please contact Beth Young who will send you the permission forms that need to be signed. The gene sequencing information will be sent to you and your veterinarian. You will be asked to complete a survey – please indicate to Dr. Young if you wish to provide the information in writing or by telephone.

If you are currently experiencing clinical problems due to PRRS virus, we would like you to participate. Affected pigs or tissues from affected pigs will have to be sent to the Animal Health Laboratory for evaluation. The pathologists will attempt to identify the PRRS virus from these pigs using a PCR test. The cost of these diagnostic tests will be your responsibility. If the PCR test is positive then the research grant will pay to have the gene sequence done on the sample. You will receive a complete report from the pathologists, including the gene sequence information. If you wish to participate in the study and have the project pay for the gene sequence, please contact Dr. Young. Let her know if you wish to complete the survey in writing or by the telephone.

CONCLUSIONS

This research will identify the commonalities between swine units infected with PRRS viruses that have the same or a similar gene sequence. The results will shape management changes in the swine industry to reduce the spread of PRRS virus in our industry.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the funding provided for this research by Ontario Pork and the cooperation of the producers and veterinarians who have already participated in the work.

ON-FARM EXPERIENCE WITH SWINE LIQUID FEEDING: RESEARCH UNIT AT ARKELL SWINE – UNIVERSITY OF GUELPH

Dan Columbus, Julia Zhu, Drew Woods, Jay Squire, Eric Jeaurond and Kees de Lange
Department of Animal and Poultry Science
University of Guelph
Guelph, Ontario N1G 2W1
E-mail: cdelange@uoguelph.ca

ABSTRACT

The swine liquid feeding system at the University of Guelph has now been operational for about 1½ years. Two unique features of this Big Dutchman liquid feeding system are that a new batch of liquid feed is prepared for each feeding and for individual troughs, and that liquid feed is moved to the feeders using high-pressure air. Since its installation, several adjustments have been made to the system, especially to accommodate the use of dry and high moisture corn, and the functionality of the system has been evaluated. In this short paper these adjustments are described and our practical experiences with the system are summarized. Growth performance and feed efficiency of growing-finishing pigs on the liquid feeding system are at least as good as those achieved on a conventional feeding system where pigs are fed pelleted feed. Growth rate of starter pigs on the liquid feeding system is somewhat lower as compared to conventional dry feeding of pelleted diets, largely because of feed intake restriction.

INTRODUCTION

During the spring of 2004 a liquid feeding system was installed at the Arkell swine research station of the University of Guelph. The system is used to support the research program on swine liquid feeding that was developed in close collaboration with the swine liquid feeding association and that is supported by a number of organizations (www.slfa.ca).

This system was chosen to more closely monitor feed delivery and feed usage in individual troughs. Two unique features of this Big Dutchman liquid feeding system are that a new batch of liquid feed is prepared for each feeding and for individual troughs, and that liquid feed is moved to the feeders using high-pressure air. These features are different from conventional liquid feeding systems that prepare batches of feed for several troughs at one time and that use water or feed to move the feed to the trough. The entire system can be controlled and monitored from a remote computer via a modem or the internet.

In this short paper, practical experiences with the system are outlined.

BRIEF DESCRIPTION OF THE SYSTEM

Figure 1 provides a general overview of the feed kitchen. The system can handle seven dry components and five liquid components. The dry feed components are stored in three large bins or four small 150 kg stainless steel bins. The small bins can be used for low inclusion premixes or complete feeds that are used in small quantities, such as phase I pig starter diets. Liquid components are stored in two 5000 kg tanks or three 2500 kg fermentation tanks.

Figure 1. Overview of feed kitchen of the liquid feeding system at the University of Guelph.



Fermentation tanks are placed on load cells to monitor weight and are equipped with probes to continuously monitor pH (acidity) and temperature of the contents. Each of the liquid components tanks has its own stainless steel stone trap and computer controlled pump. Each of the tanks is fitted with agitators, a washing system and 2 fogging units to enter two different cleaning agents (e.g. acid and base) in the tanks. When we use high moisture corn, it is ground in batches and then moved immediately into the liquid tank where it is stored mixed with water (in a 1 to 2 ratio; about 26% dry matter) and agitated hourly until use. Typically, a new batch of high moisture corn is prepared once a week.

Central to the liquid feeding system is the 80 kg mixing tank (Figure 2). The tank is placed on load cells and receives dry components from the seven short horizontal augers that are placed directly above the mixing tank. The short augers and small feed holding bins above the mixing tank enhance accuracy of dry component delivery to the mixing tank. Liquid components are entered via the top or bottom of the mixing tank. Each liquid component has its own line leading to the mixing tank with computer-controlled valves. Both cold and warm water can be used to prepare the liquid feed. Once the feed components are delivered and the liquid feed is mixed, the mixing tank is sealed and air pressure is then used to move the liquid

feed to the troughs through a one-inch (25mm) feed line. A small amount of water is used to rinse out the feed line after each delivery of feed. Feed preparation and delivery is computer controlled and a new batch of feed can be prepared every 2 to 3 minutes. The mixing tank is equipped with a cleaning system, similar to that for the liquid component tanks.

Figure 2. Feed mixing tank of the liquid feeding system at the University of Guelph.



The 24 valves that control the liquid feed to each of 24 feed troughs are positioned in the hallway and outside of the pig rooms. There are two additional valves in the feed line; one valve at the end of the feed line is used to dispose of cleaning water and one valve at the beginning of the line is used for liquid feed sampling. Liquid feed is delivered to two identical rooms, with 12 pigpens each. Each pen can hold 16 starter pigs or 8 grower-finisher pigs. Heat lamps can be used to provide additional heat to young pigs.

Feed troughs (Figure 3) are placed on small concrete pads to correct for the slight slope in the partly slatted floors and can be exchanged to accommodate starter pigs or grower-finisher pigs. Each trough has a sensor to check whether feed is present in the trough prior to feeding. The dimensions of the troughs are provided in Figure 4. Trough width available per pig is 6.5" for starter pigs and 13" for growing-finishing pigs, so that all pigs can eat simultaneously. Special features of this design are the small lips at the top of the trough and the bars inside the trough that are spaced 13" apart for both starter and growing-finishing pigs. The cross-bars inside the trough prevent pigs from lying in the trough and limits (it does not prevent!) the pigs from moving the (stale) feed towards the ends of the trough.

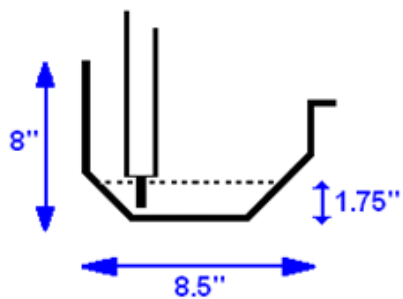
Figure 3. Feed troughs used in the liquid feeding system at the University of Guelph. The height of the concrete pad underneath the feeder varies from 1" on one side to 4" at the other side to correct for slopes in the floor.



Figure 4. Schematic cross-section of the feed troughs used in the liquid feeding system at the University of Guelph. The dotted horizontal line represents the position of the cross-bars inside the feeders.

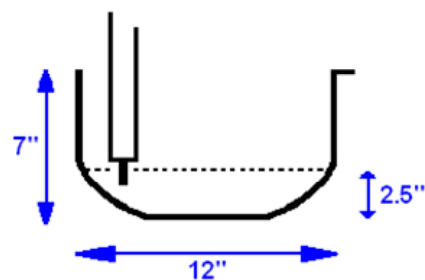
WEANER TROUGH

- TOTAL TROUGH LENGTH = 106.5"
- SENSOR HEIGHT = 0.25" to 0.5"
- DISTANCE BETWEEN CROSSBARS = 13"



GROWER/FINISHER TROUGH

- TOTAL TROUGH LENGTH = 106.5"
- SENSOR HEIGHT = 1"
- DISTANCE BETWEEN CROSSBARS = 13"



PRACTICAL EXPERIENCE WITH THE LIQUID FEEDING SYSTEM

General management

After the system was installed, some minor modifications have been made:

- The connection rings and couplers between the agitator gearbox and fiberglass storage tanks had to be reinforced to deal with resistance of agitating more dense liquid mixtures like high moisture corn.
- The diameters of the feed lines between the liquid feed ingredient tank and the stone trap has been reduced (from 3" to 1.5"), as well as the volume of the stone-trap. Given the relative slow speed of moving liquid components, these lines slobbered full with dry matter of the feed ingredients and became plugged, especially when high moisture corn was used.
- For most of the liquid feed ingredients the entrance into the mixing tank has been moved from the bottom to the top of the mixing tank. This has reduced variation in after-flow of liquid components and thus accuracy of feed preparation.
- A pressure reducer was inserted in the water lines, to ensure a constant flow of water into the mixing tank.
- The cold water lines have been insulated with plastic foam in order to reduce water condensation and dripping from the water lines.
- The air exhaust from the mixing tank was changed from a solid PVC pipe to a soft flexible tube. The solid pipe interfered with the load cells and thus accuracy of weighing of components into the mix tank.
- The stirring paddles inside the mixing tank were made heavier (reinforced). Especially when corn was used, some feed was building up in the mixing tank, resulting in the alarm "mixing tank not emptying".
- The long, grey, solid PVC feed delivery line in the hallway was replaced with a transparent pipeline. This made it easier to identify blockage of the feed line.
- Some of the stators in the pumps at the liquid feed ingredients tank had to be replaced. Apparently (high) moisture corn wears the rubber inside the stators of these pumps down more quickly than other feed ingredients. In hindsight, these worn down stators were the main reason for blockages of lines between the liquid feed ingredient tanks and the mixing tank.

We have had substantial numbers of blockages in the main feed delivery line. We learned quickly that the system can not handle complete pelleted feeds; these problems were alleviated by crumbling the pelleted feed. To eliminate blockages of the feed delivery lines we are now maintaining the water to feed dry matter ratio above 2.6:1. In the future we may explore lowering this ratio and allow a longer soaking time in the mixing tank to reduce the incidence of blockages. Alternatively, the routine use of a more viscous ingredient, such as corn distillers solubles or corn steep water, may better maintain feed homogeneity and reduce blockages. The use of viscous ingredients may reduce the energy cost of moving feed through the system as well.

A series of tests was conducted to check accuracy of feed delivery to individual feed troughs and to establish typical feed intake curves and pig performance levels for this unit and the Arkell pure-bred Yorkshire pig herd. Based on 12 samplings, the actual dry matter content of

individual batches of feed was $25.17 \pm 1.06\%$ - which was not different from the target value of 25.0% - while the amount of dry matter delivered was always within 5% of the targeted amount.

In terms of cleaning, the feed lines are flushed with about 10 to 30 liters cold water (varying with the number of meals per day) between feeding different diets, which is disposed of in the manure pits. Since we installed the transparent feed delivery pipeline, we have noted that some feed is left in the feed lines after each feeding, which is removed with the flush water. Initially, the mixing tank and the feed lines were cleaned with acids followed by base solutions once a week. Now we only do this between experiments. This change has not resulted in any apparent reductions in feed intake or growth performance of the pigs. We have not noticed any apparent build of mould, yeast or bacteria in the system, but we have not yet tried to quantify these organisms in different segments of the feed lines or in the feeders.

With the trough designs we have had little feed wastage, little fouling of the troughs, nor have pigs been stuck underneath the cross-bars inside the trough. Initially, we did not use the sensors much and adjusted the feeding curves when feed troughs were not emptied within 2 hours after feeding. At that time the feeding level was not changed by more than 10% between subsequent days. More recently, and now that we have established some reasonable feed intake curves, we have started to rely more on sensors to regulate feed delivery. During the first week after weaning and in some pens every 2nd meal may be skipped, meaning that feed can stay in the trough for about 4 hours and that these pigs may only receive three meals on some days. Rarely, however, do we have to remove stale feed from the troughs. When growing pigs are first introduced to the system, they may skip one out of four meals per day for about the first week. For both the starter pigs and grower pigs, the number of skipped meals is minimal after the week, and feed is generally eaten within one hour after feeding. This means that the pigs are not truly fed *ad libitum*.

Growth performance of growing-finishing pigs

In a growing-finishing pig performance study, conventional dry feeding was compared to liquid dry corn or high moisture corn based diets. There were 8 pens with 8 pigs per pen for each of the three treatments. Liquid fed pigs were fed equal meals four times daily, at 0600, 1000, 1400 and at 1800 h; at feeding all pigs were able to eat simultaneously and trough sensors were used to monitor liquid feed delivery. In the conventional dry feeding system, pigs were fed *ad libitum* from single space feeders. Good growth performance was achieved on all treatments (Table 1). In addition to conventional growth performance, we monitored animal behavior (using video cameras), feed digestibility, fecal excretion of lactic acid producing bacteria (LAB) and coliform bacteria, water usage and aspects of pork meat quality. In this study, we did not observe a growth performance advantage of liquid feeding of grower-finisher pigs. However, feed efficiency was about 5% better when pigs were fed high moisture corn through the liquid feeding system.

Table 1. Impact of feeding strategy on performance of growing-finishing pigs.

	Conventional feeding, dry pelleted feed	Liquid feeding, dry corn	Liquid feeding, high moisture corn
Initial Body weight, kg	23.5	23.7	23.4
Final Body weight, kg	104.7	105.8	104.2
Gain, kg/d	982	1011	1009
Feed:Gain (88% dry matter basis)	2.63	2.64	2.51
Carcass dressing (%)	82.2	80.4	82.5
Carcass lean yield (%)	61.2	60.9	61.0
24 pH loin	5.54	5.56	5.55

Treatment effects on pig behavior were observed, but only after pigs were adjusted to the feeding systems for about 5 weeks (Table 2). Pigs raised on liquid feeding systems spend more time lying and less time nosing other pigs than pigs on the conventional dry feeding system.

Table 2. Impact of feeding strategy on proportion of time (fraction of time \pm standard error) that pigs were involved in different behaviors*.

Behavior	Feeding system		P value
	Liquid (n=16 pens)	Dry (n=8 pens)	
Lying	0.829 \pm 0.007	0.799 \pm 0.007	0.023
Nosing	0.011 \pm 0.002	0.024 \pm 0.003	0.002
Sitting	0.015 \pm 0.002	0.022 \pm 0.002	0.018
Active	0.040 \pm 0.005	0.047 \pm 0.007	0.507
Social	0.002 \pm 0.001	0.003 \pm 0.001	0.316
Fighting	0 \pm 0.0002	0 \pm 0.0002	0.671
Feeding	0.040 \pm 0.003	0.046 \pm 0.004	0.149
Drinking	0 \pm 0.005	0.003 \pm 0.006	<0.001

* Observations were obtained using video camera and about 5 weeks after pigs were assigned to the two different feeding systems.

Newly-weaned piglets

In a starter pig study, we compared (1) a conventional dry feeding program, (2) liquid feeding the conventional dry feeds, and (3) liquid feeding where all whey was removed from the dry feed and replaced with condensed liquid whey permeate on a dry matter basis. Pigs were introduced to the dietary treatments at weaning (17 to 21 days of age; average body weight 5.76 kg) and not fed any in-feed antibiotics in any of the treatments, with 8 pens of 16 pigs per treatment. Of the 8 pens of pigs that received condensed whey permeate, 4 pens received reducing levels of whey permeate (20/10/0 of dry matter during three phases with gradual transition) while 4 pens received a constant level of whey permeate (20% of dry matter). Liquid feeding was computer controlled and based on 6 equal feedings per day (0600, 0900, 1200, 1500, 1800, 2100 h); no feed was delivered when the previous meal was not consumed

completely, monitored by sensors in each individual trough. Best performance was observed for dry feeding (Table 3), likely because of feed intake restriction in liquid fed pigs. Among the liquid fed groups, body weight gain was improved when whey permeate was included in the diet (377 vs. 331 g/d during the first 6 weeks post-weaning). Additional analyses are underway to assess pig behavior, nutrient digestibility, gut health, and gut development.

Table 3. Growth performance of newly weaned piglets.

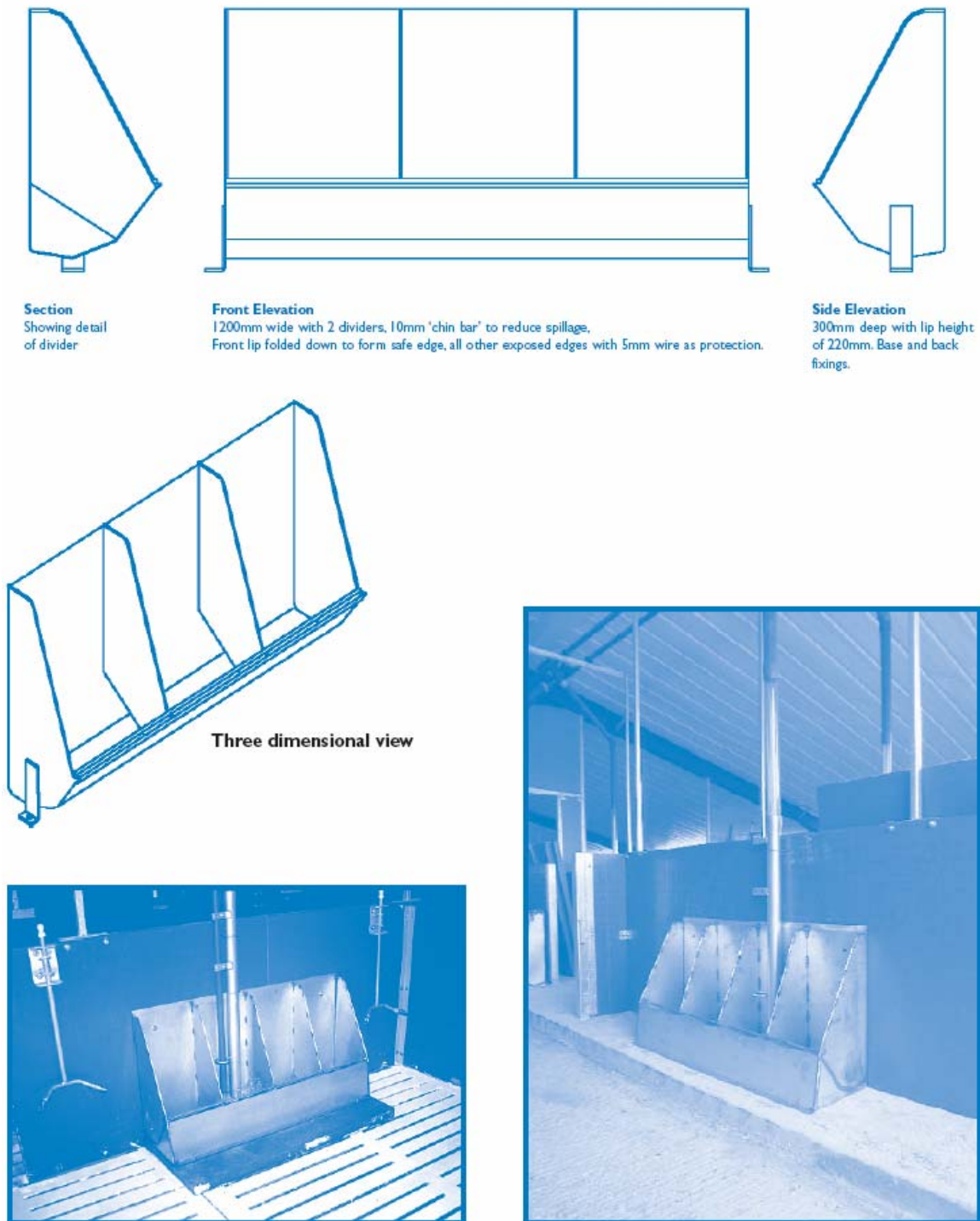
	Conventional feeding dry	Liquid feeding 'dry feed'	Liquid feeding 'condensed whey permeate'	
			Step-down	Constant at 20%
Initial Body weight, kg	5.76	5.76	5.87	5.67
Daily gain, g/d				
Day 0-7	99	87		95
Day 28-42	616	541	509	616
Day 0-42	399	334	331	377
Feed:gain				
Day 0-42	1.41	1.50	1.53	1.42

CONCLUSIONS AND ADDITIONAL CONSIDERATIONS

During the spring of 2004 a liquid feeding system was installed at the Arkell swine research station of the University of Guelph. The system is used to support the research program on swine liquid feeding that was developed in close collaboration with the swine liquid feeding association and that is supported by a number of organizations. Several adjustments have been made to the system, especially to accommodate the use of dry and high moisture corn. The system was deemed accurate in delivering the intended amounts of feed to individual feed troughs. Growth performance and feed efficiency of growing-finishing pigs on the liquid feeding system are at least as good as those achieved on a conventional feeding system where pigs are fed pelleted feed. Growth rate of starter pigs on the liquid feeding system is somewhat lower as compared to conventional dry feeding of pelleted diets, largely because of feed intake restriction.

The system at the University of Guelph is using long troughs, based on meal feeding and does not allow steeping of mixed feed before feed delivery. This is in contrast to ad libitum feeding systems that use short troughs, such as at the Stotfold pig development unit in the UK. In that system, 20 kg batches of feed are delivered whenever the feed level in the trough is lowered below the sensor. Moreover, liquid feed is prepared in large batches and is allowed to steep in the mixing tank. From midnight to about 2:00 am, no feed is delivered to ensure that the troughs are emptied at least once per day. The design and dimensions of these troughs are given in Figure 4. This system supports growth performance of growing-finishing pigs that is slightly better as compared to a conventional dry feeding system. In these studies, pigs are fed barley and wheat, rather than corn based diets, which may have contributed to the advantage to liquid feeding as well. The Stotfold system has not been used for starter pigs.

Figure 5. Schematic of feeders used in the liquid feeding system for growing-finishing pigs at the Stotfold pig development unit in the UK (www.stotfoldpigs.co.uk/ Courtesy Dr. P. Gill).



ON-FARM EXPERIENCE WITH SWINE LIQUID FEEDING: GROW-FINISH PIGS

Leroy Van Ryswyck
Embro, Ontario N0J 1J0
E-mail: squealsR4meals@netscape.ca

ABSTRACT

At the Van Ryswyck farm a single-line, single mixing tank liquid feeding system and auto-sorter were installed in 2001. After some initial challenges with ad-libitum feeding we have fine-tuned our feeding program and how we use our liquid feeding system. Since implementing these changes we are achieving good growth performance and carcass quality. Both technologies have helped to reduce feed costs and labour in our operation.

INTRODUCTION: BRIEF DESCRIPTION OF THE SYSTEM

Our operation consists of a 1400 head wean to finish facility located in Oxford County. The early wean facility is run on an all in all out basis using complete feeds. The finishing facility consists of two rooms which are run on an all in-all out basis by room. The finishing facility was renovated in 2001 to go to total slatted flooring and utilize liquid feeding and auto sorting technologies. Each room holds 450-500 finishing pigs with dimensions of 12.2 m x 27.4 m per room to provide 0.74 to 0.67 m²/pig (Diagram 1).

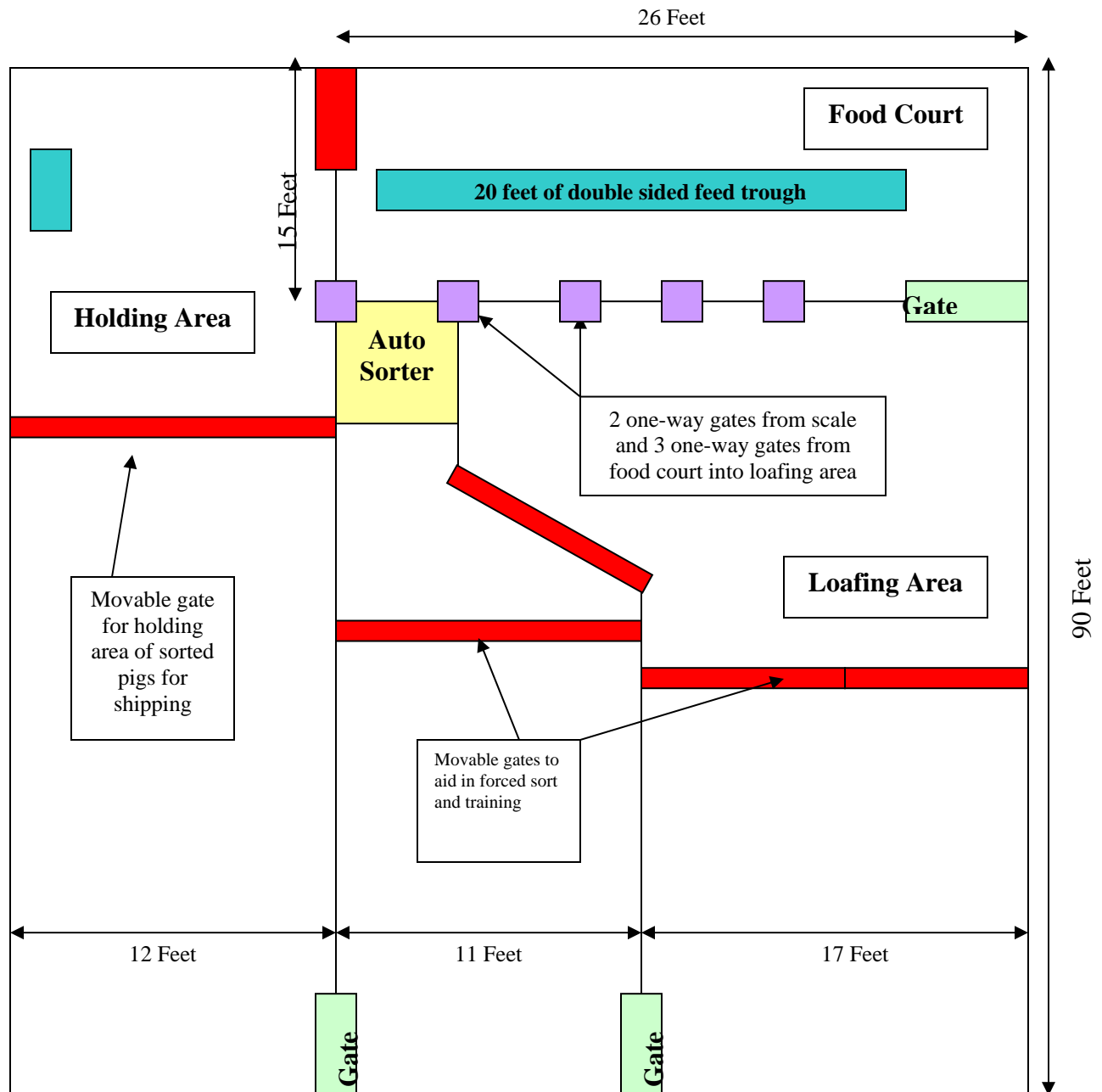
The liquid feeding system utilizes on farm grown high moisture corn, concentrate and a condensed whey containing 37% dry matter. It is a single line, single mixing tank Hampshire system. The pump and agitation are contained in a single unit. During circulation feed pushes feed and there is feed in the line at all times. The feed in the line never sits for more than one hour without being re-circulated and brought back to the tank for agitation. The feeding system checks the probes in the troughs a minimum of once per hour.

The liquid system is what I call a semi ad-lib system. The difference between this and a fully ad-lib system is that each room is fed a different ration depending on the pigs' weight. Therefore a room is fed its ration based on weight for 2 hours while the other room is in a rest period. I personally prefer this method because it matches the correct ration with the desired weight range and allows for less feed wastage than a traditional ad-lib system by restricting feed delivery during the rest period.

There are nine pigs allocated per feeder space, which in my opinion is the bare minimum for optimum growth. Current recommendations are for 1.5 inches of trough per pig making my trough about 8 feet short. The auto sorter was originally used as the only entrance to the feed court but soon after installation of the system I believed that pig flow to the feed court was compromised by time. Therefore we added one gate, which I leave open all of the time to the feeding court as well as opening a moveable gate at the back of the food court to allow easier

access to feed. The only time these gates are closed is during a forced sort or during a training period.

Diagram 1. Layout of room design.



Training of the pigs starts at about 68 kg and is a must for a smooth transition to a forced sort. Every one to two weeks the pigs are moved compartment-by-compartment closer to the scale until they have all been weighed. I believe you must also do this once or twice during the shipping period to ensure that all pigs in the room have been weighed before shipping day. The actual training period begins with the pigs being confined by room towards where the scale will eventually be positioned. There is a corridor in the centre of the loafing area with partitions towards a funnel system. After the pigs move through where the scale will eventually be positioned, they must pass through one-way gates into the feed court. After about two training periods during which the pigs pass through without a scale the auto sort is first introduced with all doors locked open so that the pigs can pass through easily. After about 2 weeks of passing through with the doors locked open the full automation of the system is introduced and then every one to two weeks the pigs are force trained in full automation mode.

PRACTICAL EXPERIENCES, ADVANTAGES AND DISADVANTAGES

Before going to condensed whey permeate (CWP), high moisture corn (HMC) was purchased in at the end of the summer. During the filling process the blower smashed the corn so much it could not be handled in the system. Since then we have changed our handling system to make this process easier. Because we could not grow enough corn and did not want to continue to purchase HMC we added CWP to the feeding program. The addition of CWP to the program did not go as smoothly as we would have liked. Carcass backfat was initially higher than we wanted to maximize our returns at Conestoga. We worked with our feed supplier over a couple of turns to fine-tune the rations and how we feed them (Figure 1).

Some of the changes we made included:

- Better understanding of the nutritional value of the CWP. As a result we also lowered the energy level of our custom concentrate significantly.
- Reducing the amount of CWP in the diet (more due to short supply and product variation when it started coming from many different plants).
- Increased the water to feed ratio as the pigs get bigger. This dilutes the nutrient density of the diet in the finishing stage. Also we felt that this was a benefit in the summer as the liquid feed is really the main source of water for the pigs.
- Went to three phase feeding to more closely match the nutritional requirements to the weight of pig.
- Implemented the semi ad-libitum feeding versus as-libitum feeding.

Since we made these changes the carcass quality improved to our target level without sacrificing any growth or days to market (Figures 2 and 3).

Figure 1. Van Ryswyck liquid feeding program.

Final body weight, kg	115		
Initial body weight for each ration, kg	25	50	75

Dry matter liquid, %	20.5	19.5	18.5
Dry matter standardized, %	88.0	88.0	88.0
Dry matter of air dry, %	88.7	88.9	89.4
Ratio water to standardized dry feed	3.29	3.51	3.76
Ratio water to absolute dry matter	3.88	4.13	4.41

Composition (%) air dry basis	Ration 1	Ration 2	Ration 3	air dry DM	DM as fed
Corn	69.8	70.7	69.0	88.0	71.0
Whey Permeat McNess	5.0	7.5	12.5	97.5	41.2
VanRyswyck Whey Supp2	25.2	21.8	18.5	89.0	89.0
Total	100.0	100.0	100.0		

On basis of standardized DM:

Actual energy kcal DE / kg	3162	3174	3187
Actual energy kcal DE / kg of liquid feed	737	703	670
Actual total lysine, %	0.96	0.86	0.77
Crude Protein, %	15.6	14.4	13.1
Calcium, %	0.62	0.56	0.51
Phosphorus, %	0.53	0.50	0.49
Available Phosphorus, %	0.23	0.22	0.22
Ca / P	1.18	1.11	1.04
Sodium, %	0.17	0.17	0.18
Copper, ppm	125	108	91

Composition (%) on basis of absolute dry matter	%	%	%
Corn	69.2	69.9	68.0
Whey Permeat McNess	5.5	8.2	13.6
VanRyswyck Whey Supp2	25.3	21.9	18.4
Total	100.0	100.0	100.0

Composition (kg) on basis of liquid dry matter	Quantity As fed	Quantity As fed	Quantity As fed
Corn	299.7	288.1	265.7
Whey Permeat McNess	41.0	58.4	91.8
VanRyswyck Whey Supp2	87.4	71.8	57.3
Water	1071.9	1081.7	1085.1
Total	1500.0	1500.0	1500.0

Figure 2. Average fat depth (mm) by month.

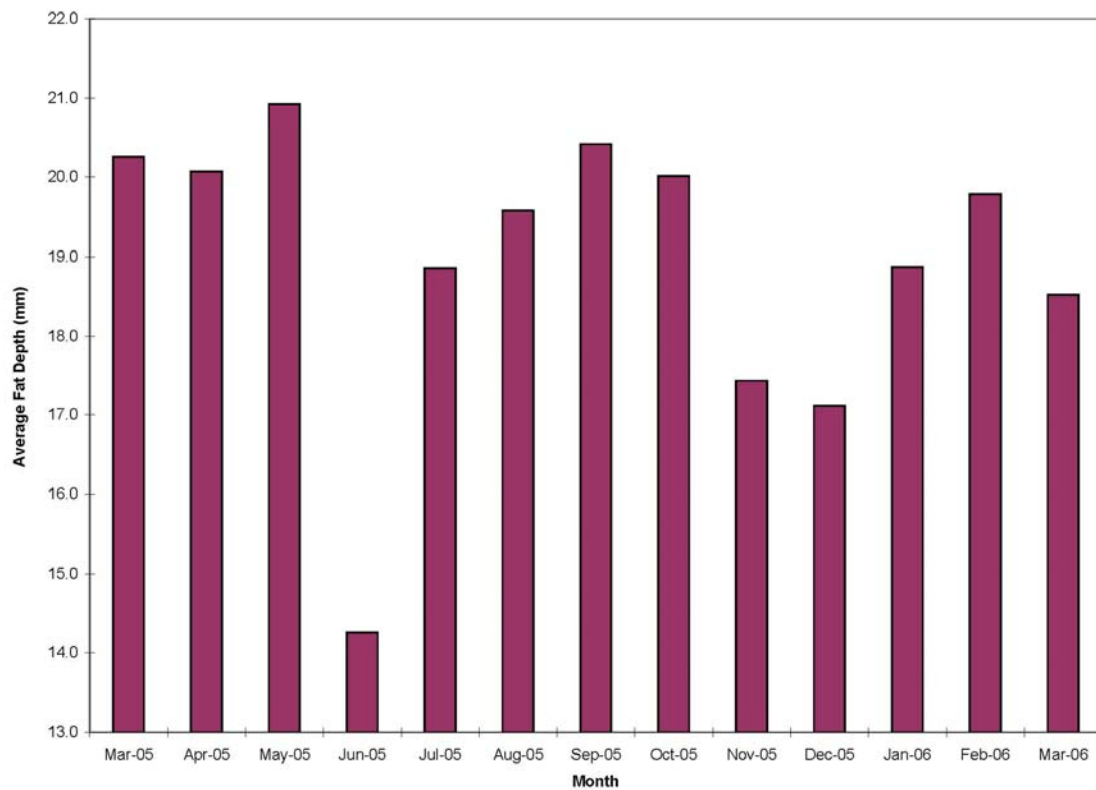
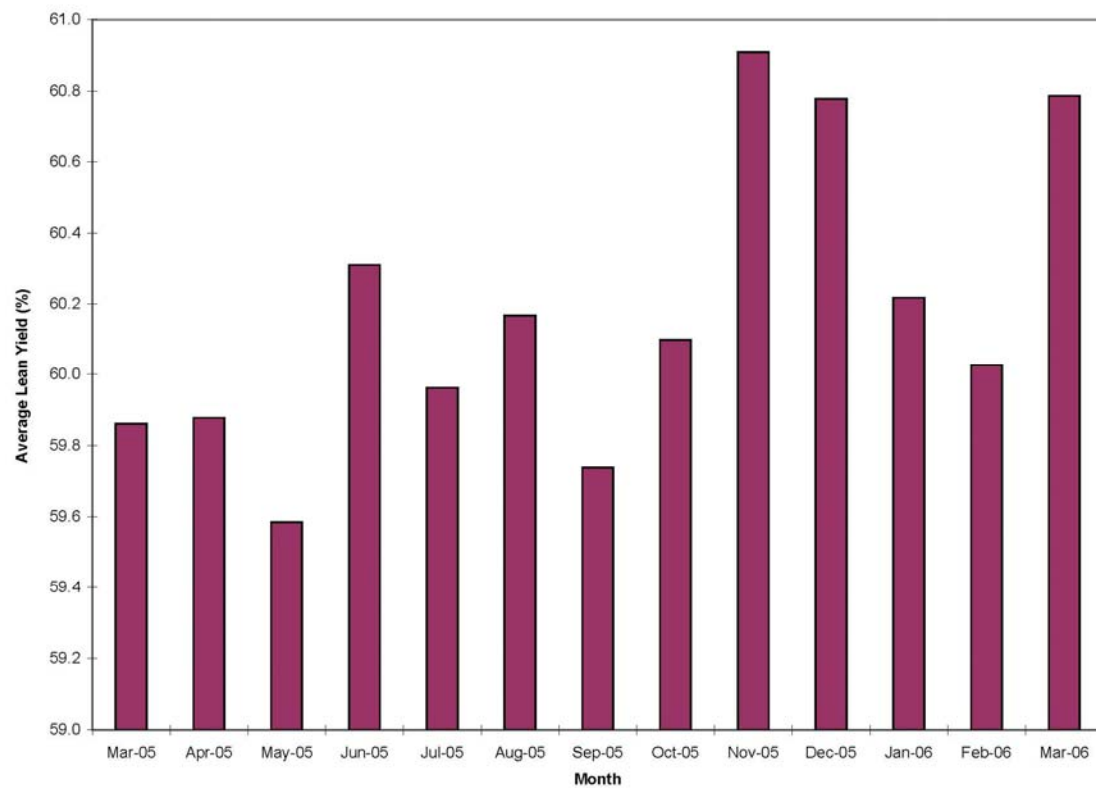


Figure 3. Average lean yield (%) by month.



The liquid feeding system does have its advantages and disadvantages:

- The system is very power hungry because it runs so often. However, the feed remains in suspension and “fresh” at all times.
- The equipment is very temperamental to fluctuations in hydro. For example, hydro spikes have caused damage to inverters totaling \$10,000. These issues were corrected when Ontario Hydro installed taps on the transformers to limit the over supply of voltage. All panels have had surge protection installed and since the changes were made we have had no problems.
- Acidity of the CWP eats away at the infrastructure around the food court. This damage is isolated to this one area of the barn and is probably not much worse than traditional wet-dry feeders. The acidity might also be causing some slightly higher mortality due to ulcers (~1%).
- Alarms really ruin the mood.
- Labour is greatly reduced.
- The ability to use co-products and save some feed cost. Initially we were saving up to \$5/pig and this has probably declined as we reduced the amount of whey in the rations.
- Pigs love the liquid feed and they eat, eat, eat.
- Initial system not that expensive. The downside is maintenance is fairly expensive because all of the parts are from the European Union.
- Performance continues to be excellent with days to market hovering around 88.

Some of the changes which I have implemented since first starting the auto sorting include:

- Removed the scale head from the crate and positioned it in a stationary position above the crate to protect it from movement during weighing.
- Added extra gates to aid in the smoother movement of pigs closer to the scale for training and forced sorting by myself. We had an earlier problem where two small pigs could get on the scale at the same time and trigger a mistaken correct weight for shipping. Removing these smaller pigs from the pigs already sorted for shipping was a challenge. The manufacturer of the scale installed an override that consists of a predetermined weight that will automatically open the gate to the loafing area and not to the pre-shipping area if the weight exceeds the predetermined setting.

Overall I am extremely pleased with both the auto sorting and liquid feeding. A couple of things which I would change would be to add more trough area for feeding and give more space allowance leaving the scale into a sometimes congested feed court.

ON-FARM EXPERIENCE WITH SWINE LIQUID FEEDING: NURSERY PIGS

Fred Tinholt
RR #2, Gorrie, Ontario N0G 1X0
E-mail: fctinholt@aol.com

ABSTRACT

At the Tinholt farm a two-line and two-mixing-tank liquid feeding system for nursery pigs was installed in 2002. After some initial challenges, especially with trough management, good pig growth performance is now being achieved. For about the first two weeks after the 17 to 20 day old pigs arrive, feed intake and growth performance are somewhat reduced as compared to conventional dry feeding system, but thereafter growth performance improves rapidly. Largely because of using co-products, slight improvements in feed utilization due to steeping, and reduced use of medication, feeding costs are lower and profits are slightly higher than dry feeding systems. Main drawbacks of the system are the high initial investments and the higher level of skill required to manage the system.

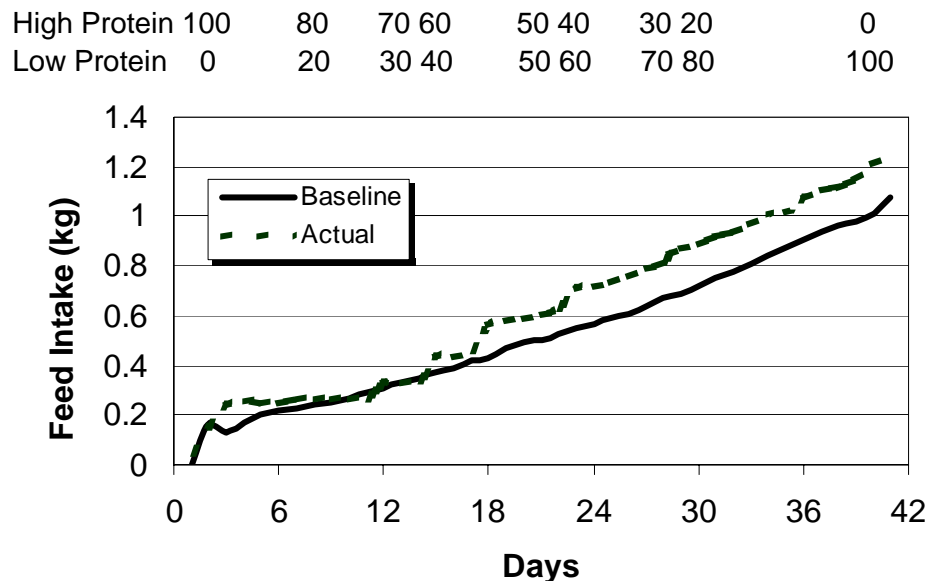
INTRODUCTION: BRIEF DESCRIPTION OF THE SYSTEM

The Tinholt's family farm has a 5200 head nursery that is managed on an all in-all out basis by room. A two-line and two-mixing-tank liquid feeding system was installed in 2002. The liquid feeding system is used to deliver two different diets ("high protein" and "low protein") to each trough. During the first 32 days of the feeding period, the composition of the feed that is delivered to the troughs is gradually changed from 100% "high protein" to 100% "low protein" (Figure 1), and stays on the 100 % "low protein" until the pigs are shipped. Each of the two mixing tanks can hold up to 2500 kg of mixed liquid feed. A new batch of the two diets is made as needed and allowed to steep in the mixing tanks between 2 and 12 hours. The main ingredients are a custom complete dry feed blend, a high dry matter whey (38 %), a low dry matter whey (6%), and a liquid fish product. Dry matter levels are typically at 34 % for the high protein and 30 % for the low protein.

New batches of newly-weaned pigs, 16 to 18 days old, arrive in the morning. Pigs are placed in pens sorted only as barrows and gilts, with 135 pigs per pen and 3 ft² per pig. Additional sorting, for size, is done after the pigs are 2 to 3 weeks in the barn. The feed troughs are placed in the centre of the pens. There is 1.6-2" trough width per pig in the pen. When the pigs first arrive, about half of them can eat at the same time. Towards the end of the nursery period only about one quarter of the pigs can eat at the same time. For the first three days, extra water is added to the trough along with the feed. The system is ad lib, so feed is added whenever the 2 sensor rods indicate feed levels are low, according to the curve (Figure 1). As the pigs grow, the frequency with which feed is added increases. For the first 2 weeks, feed will be added 9-18 times per day, during the last week, feed may be added as many as 50

times per day. In each pen there are 2-3 nipple drinkers allowing the pigs to always have access to fresh water.

Figure 1. Target and actual feeding curve and changes in proportion between the “high protein” diet and the “low protein” diet.



PRACTICAL EXPERIENCES, ADVANTAGES AND DISADVANTAGES

For the first few batches of pigs, growth performance was rather disappointing, largely because of lack of experience in trough management and lack of reasonable feeding curves. Since that time we have replaced our feed troughs (Figure 2) and have come to accept somewhat reduced feed intake (Figure 1) and growth performance for about the first two weeks. Thereafter, feed intake and growth increases rapidly. We now routinely generate average final body weights of 26 kg for batches of 1,000 pigs over a 50-52 day period. Overall, our production costs are lower than in our contract dry fed 2nd nursery, largely because of the use of relatively inexpensive co-products.

The following are the advantages of the system:

- Optimizing gut health and reduced medication use: Typically and for a batch of 5200 pigs, we will lose 150-175 pigs and have to move 150 pigs to off-sort (restart) pens. Pigs that are moved to the off-sort pens receive dry feed and are treated with injectable antibiotics. About half to two thirds of these pigs can be moved back onto the liquid feeding system, while the remaining pigs are sold as off-sorts. We do use in-feed antibiotics at a low level, with issues like diarrhea being a minor problem. The high level of lactic acid and a pH below 4.5 in the feed help provide for optimal gut health.

Figure 2. New stainless steel feeders for nursery pigs.



- Steeping feed: During ‘storage’ of feed in the mixing tank some fermentation occurs. This allows some growth of beneficial lactic acid producing bacteria and may improve feed digestibility. Steeping appears to enhance feed utilization and helps aid in digestibility as dry feed is given time to absorb some water.
- Co-product use: We routinely use whey and whey permeate to reduced feed costs.
- Improved feed intake in later growth: Growth performance during the last 4 weeks is better than what we experienced previously with conventional dry feeding systems.
- Flexibility with feeding program: We have 4 storage tanks for liquid feed ingredients. When opportunity ingredients are available we can use them easily and quickly.
- Reduced feed costs and improved profits: This is the combined result of use of inexpensive co-products, better feed utilization, reduced need for in-feed antibiotics and slightly better growth performance.

The following are the disadvantages of the system:

- Higher capital cost: The initial investment in the liquid feeding system was higher than for a conventional dry feeding system. However, given the lower feed costs, the pay back time would be expected to be 2-4 years (depends on initial investment, feed program, number of pigs fed, barn design and layout, etc.).

- Lower feed intake in early stages: To maximize feed intake during this time, it is necessary to do some extra work with the troughs, like adding extra water since the little pigs like to drink as opposed to eating the thick solids sitting on the bottom of the troughs.
- Higher management level: Management of a liquid feeding system requires additional skills, including working with computers, fixing plugs in feed lines or replacing broken valves, and early identification of poor doing pigs.
- Higher yeast and bacterial risk: We normally only clean the system thoroughly between batches of pigs, and we have had no serious problems with bad yeasts or bacteria that have reduced feed intake or caused scours.
- Trough design: The initial trough design resulted in too much feed wastage, build up of feed in corners, and with pigs getting stuck and drowning. Since that time we have moved to a simpler stainless steel trough, with cross bars that are spaced about 8" apart (Figure 2).
- Higher daily operating cost: The system does consume more energy and has higher maintenance costs than a dry feeding conventional system.
- Medication inclusion limited: With the two tank system, the challenge is medicating through the changes in the feed curves.
- Co-product consistency and supply: We routinely check the dry matter content of the liquid feed ingredients and we have learned to only buy from reliable suppliers. We were using a waste soft drink product and a waste milk product, but inconsistencies made these too hard to work with. By the time a sample was taken and tested, the load was almost gone.

ENERGY EFFICIENCIES - STRATEGIES FOR MINIMIZING UTILITY COSTS IN THE BARN

Harry Huffman, Huffman Engineering
86 Southfield Cres., London, Ontario N6K 2B7
E-mail: harryhuffman@rogers.com

Ron MacDonald, Agviro Inc.
367 Gordon Street, Guelph, Ontario N1G 1X8
E-mail: rmacdonald@agviro.com

ABSTRACT

This paper discusses the importance of maintaining both the desired environmental temperature for the pigs being housed as well as exchanging sufficient air to maintain good air quality for maximum pig performance. Equipment sizing and efficiencies are discussed as well as proper control of these devices. Additionally, various lighting options are discussed since this is another significant energy user in many swine enterprises. The paper concludes with comments regarding heat recovery, possible alternative fuels and renewable energy sources.

INTRODUCTION

Energy prices have escalated rapidly in the last few years. Natural gas has risen from as low as \$0.80/GJ to \$8.00/GJ, a ten-fold increase. No other segment of farm costs has risen as quickly. Energy may still be a small percentage of overall annual expenses, but it is an essential input. Wasting energy not only wastes money, it causes pollution in the form of greenhouse gas emissions, and it has also been shown that the quality of indoor air and overall swine barn environment can be lowered. As a result, it makes good sense to manage our energy resources wisely.

This paper focuses on the main consumers of energy in barns (Heating, Ventilation, Lighting) and energy efficient technologies.

COST OF ENERGY/ CONTRACTING

Energy costs have risen very rapidly in the last few years, Natural gas has gone from as low as \$0.11/m³ to about \$0.42/m³ (February 2006). Electricity prices have risen from \$0.08/kWh to \$0.11 and further increases are already scheduled.

Contracting natural gas can be arranged for one through five years. Typically the longer time periods have been the best bet for saving money. Short term has not been as valuable as simply staying with the market prices so far.

For small farms, staying with the price cap is recommended in the electricity world.

To evaluate various pricing and contracts, the best way is to check out www.energyshop.com, an independent company that will provide energy pricing from all companies selling gas and electricity. As well, the Ag Energy cooperative at www.agenergy.coop has new long and short term deals worth looking at.

HEAT BALANCE AND AIR QUALITY

The two main goals in every livestock room environment are to maintain the room temperature within the comfort zone of the animals being housed and to also exchange sufficient air to maintain good air quality for both the animals and the stockmen. During the three cooler seasons of the year, the amount of air exchange provided can affect the room temperature. If the animals are not able to provide sufficient heat energy to offset the building shell losses plus the heat loss with the ventilation air, then the room temperature will be lowered. Of course, the remedy is to add sufficient supplementary heat to make up the difference or balance the heat flow. Heat gains must equal the heat losses to maintain a consistent room temperature.

Let's look at a 500 pig capacity nursery room as an example of typical heat gains and losses. Typically these rooms start the pigs off at a relatively warm room temperature in the range of 29 or 30C depending on the weaning weight and then slowly allow the room temperature to drop over the next 6 to 8 weeks to approximately 21 or 22C. Even though this room will be reasonably well insulated, it will lose heat energy through all of the walls, ceiling, floor and foundation. These shell losses will reduce as the room temperature is lowered. The other main heat loss is that which exits through the ventilation fan. Interestingly, this heat loss continues to get larger as the pigs grow even though the room temperature is being lowered. This is due to the fact that more ventilation is required as the pigs grow to maintain good air quality. Since the small pigs do not provide a lot of heat energy to offset (or balance) these heat losses, supplemental heat must be added to maintain the desired room environment. But; how much heat? Table 1 summarizes the heat energy flows for this example nursery room.

Table 1. Heat balance table for 500 pig nursery room.

Room Parameter	4 Kg Pigs	7 Kg Pigs	10 Kg Pigs	18 Kg Pigs	27 Kg Pigs
Room Temp / RH	30C / 57%	29C / 60%	26C / 62%	23C / 64%	21C / 66%
Ventilation Rate CFM	550	750	900	1300	1600
Outside Design Temp	-12C	-12C	-12C	-12C	-12C
Room Shell Losses BTUH	31530	29570	24190	19800	16085
Ventilation Loss BTUH	51480	65390	71880	94500	115180
Total Heat Losses BTUH	83010	94960	96070	114300	131265
Heat Gain from Pigs	17690	30210	53100	92170	131265
Heat Balance BTUH	-65320	-64750	-42970	-22130	0

The interesting fact from this example is that the exhaust fan heat loss accounts for 62% of the losses with very small pigs and increases to 88% of the total heat losses for the largest pigs. Additionally, the total heat energy leaving the room increases by 58% as the pigs grow. Thus, the actual ventilation rate provided for the room really does impact the energy requirement for nursery pigs. Therefore, precise control of the air flow exchange rate is paramount to minimizing energy usage.

However, simply reducing the ventilation rate is not a good operating strategy, since air quality will deteriorate and resulting pig performance is often compromised. The key is to exchange enough air but do not over ventilate. This means sizing the stage 1 ventilation fan correctly and then controlling both it and the heater such that they work together and do not waste energy.

VENTILATION & HEATING EQUIPMENT SIZING

Generally properly sized equipment performs the best job and does it efficiently. With ventilation fans, this is a relatively easy task since we tend to provide at least 4 stages of ventilation from the winter minimum to the summer maximum rate. Even with the use of variable speed fans, most rooms will be equipped with at least 2 fans and more often than not, three or more exhaust fans. Having said that, it is still possible to over size the stage 1 (minimum fan) fan such that it is not able to run continuously and thus waste energy and promote earlier wear out. Starting an electrical motor generally takes at least 3 times the energy as it does to simply keep it running. However, an over sized fan is sometimes necessary. If the room is quite small or the animal population very low it may be difficult to purchase an exhaust fan with a low enough output to be able to run continuously. For this case, a timer function on the controller is workable until the pigs are larger or the weather warmer such that the fan can be operated continuously. Occasionally a large room may require several stage one fans to provide a reasonable spacing for exhaust points and yet need sufficient capacity with the larger pigs that when the pigs are young, the fans are too big and thus a timer cycle is also required for a short time frame.

Ideally, a complete ventilation and heating analysis should be undertaken as part of the design process for a new swine facility and as such the equipment would be specifically sized for that room or rooms. However, over the years a number of rate tables have been developed based on that type of analysis and of course good practical experience working in the ventilation design field. Table 2 provides some basic ventilation rates for different sizes of pigs that can be used as a guide to help select the proper size of fans.

Fan performance can vary considerably from one fan model to another depending on type of motor and blade design as well as housing and orifice arrangement. However, Table 3 provides a ballpark range of values for typical agricultural fans found in the market place. Always consult with the manufacturers' literature and ask if it has been tested for air flow by an independent laboratory. Also refer to the Equipment Efficiencies section of this paper.

Table 2. Typical ventilation rates for pigs.

Pig Size / Type Weight in Kilograms	Minimum Winter Ventilation	Maximum Summer Ventilation
5 Kg	1.5 CFM	18 CFM
25 Kg	3.0 CFM	35 CFM
50 Kg	4.0 CFM	50 CFM
75 Kg	5.0 CFM	65 CFM
100 Kg	6.0 CFM	75 CFM
120 Kg	7.0 CFM	80 CFM
Gestation / Breeding	10 CFM	200 CFM
Farrowing	15 CFM	300 CFM

Table 3. Typical exhaust fan capacities.

Fan Size (Blade Diameter)	Minimum Capacity (variable speed)	Maximum Capacity (full speed)
12"	300 CFM	1000 – 1300 CFM
14"	500 CFM	1500 – 1800 CFM
16"	700 CFM	2000 – 2500 CFM
18"	800 CFM	2800 – 3500 CFM
20"	1000 CFM	4000 – 4500 CFM
24"	1200 CFM	5000 – 6500 CFM
28"	1500 CFM	6000 – 7000 CFM
30"	2000 CFM	7000 – 8000 CFM
36"	2500 CFM	9000 – 10000 CFM
48"	NA	18000 – 20000 CFM

With heating equipment, sizing is always a problem since we tend not to have variable output heaters to choose from in the market place. Some heaters do offer a 2-stage burn feature while others have a variable output orifice that can be manually adjusted. However, for the most part the heating equipment is sized for a cold winter day and that size is installed and used for all of the heating needs on an “on / off” basis. Thus we are forced to live with over-sized heating equipment for a good percentage of the year. There is some energy efficiency to be gained by installing a 2-stage burner or splitting the heating requirement into two separate heaters and then stage the heating with the room controller. However, the extra capital cost of either the 2-stage heater or 2 separate heaters makes the increased energy efficiency a no gain option.

Similar to exhaust fans, a detailed room analysis should be undertaken to determine the size of heater needed, but tables like the one provided here have been developed to get you in the ballpark for equipment sizing.

Table 4. Supplementary heat for pigs.

Type of Pig Room		Supplemental Heat BTUH / Pig		
		-20 C	-10 C	0 C
Weaned	4 Kg	220	170	120
Pigs	12 Kg	210	140	70
	20 Kg	200	100	25
Feeder	25 Kg	200	90	0
Pigs	40 Kg	100	40	0
Gestation / Breeding		500	250	0
Farrowing per Crate		1700	1100	450

EQUIPMENT EFFICIENCIES

Heating

Supplemental heat from various sources has been cheaper to buy than the added costs associated with extra feed, longer days to market and health problems, which can develop from the poorer quality environment caused with insufficient ventilation.

Heat is usually supplied in swine barns in two forms: 1) Convective and, 2) Radiant.

Convective heat directly heats the air. The heated air then moves throughout the space, either by a fan on the heater or as a result of the ventilation system causing air currents to move it. Convective heat systems require a warmer barn temperature than a radiant system and the use of re-circulation systems helps ensure uniform heat distribution in the barn.

Radiant heat is defined as the electromagnetic waves passing through space, which warm up an object (on contact) in the path of the waves. Radiant heat systems generally allow a cooler barn temperature because the heat energy output is used to heat the pigs, not the air. Even though the ambient temperature is lower, animal comfort is still maintained.

1) Convective Heating Systems

A) Direct-Fired Forced Air: These forced air unit heaters use propane or natural gas. The heater burns the fuel and barn air and then vents the heated air (actually the by-products of combustion) directly into the room. This is both an advantage and disadvantage for these units. The advantage is all of the heat energy available is being used in the room; none is vented up a chimney and wasted. The disadvantage is that the combusted air contains carbon dioxide (CO₂), carbon monoxide (CO) and moisture (H₂O) and consumes oxygen (O₂), which is why the barn is being ventilated to start with.

B) Hot Water Heating Systems: Hot water systems can operate using just about any fuel source, including natural gas, propane, oil and wood. They usually consist of hot water pipes around the perimeter of the barn. Today's modern "hydronic" heaters (fuelled by propane, oil

or natural gas) are quite efficient, usually around 80% or so. This system provides good quality heat because it heats the outer perimeter of the barn. It is more expensive to install and the pipes can be a problem as they interfere with cleaning, shipping, etc.

2) Radiant Heating Systems

A) Gas Tube Heaters: The most popular system is the gas tube radiant heaters, using either natural gas or propane. These units usually use outside air for combustion, but vent the by-products (CO₂ and moisture) into the barn. This again requires a higher ventilation rate, but not as high as direct-fired since it burns outside air.

B) Catalytic or Open Flame Brooders: These heaters are designed for partial room brooding, using propane or natural gas. These units concentrate their heat energy in a specific area of the pen with the intent that the pigs will be attracted to this “more comfortable” heat zone. These units are direct fired and as a result higher ventilation rates are necessary. Maintenance is critical to proper operation; improper maintenance will result in incomplete combustion and poisonous carbon monoxide gas will result.

C) In-Floor Radiant: This consists of plastic piping buried in the concrete (or sand beneath) at approximately 12" on centre. A boiler and pump system provide hot water to heat the floor surface. One disadvantage is the thermal lead/lag; it takes a while to heat the concrete mass when temperatures change quickly and conversely, it takes a while to cool down when temperatures warm up. As a result, rapid outside temperature changes make it difficult to control the barn. Costs vary widely. However, it is safe to say that this will be the highest capital cost of the many heating systems available.

Ventilation Fans

Since ventilation fans are necessary on a 24/7 basis, it only makes sense that they should be as energy efficient as possible. Several comments are in order regarding fan efficiency.

- 1) Do not use amperage to compare fan efficiency. There are too many other factors affecting performance that makes amperage extremely unreliable.
- 2) Wherever possible, use 240 V motors, not 120 V to increase energy use efficiency. Higher voltage will decrease losses that occur in the wire itself.
- 3) Try to keep the length of wire from the panel as short as possible. Less than 100' is optimum. This may mean installing an electrical sub-panel in the building somewhere.
- 4) All wiring should be #12 gauge as a minimum, to reduce line losses.

Another motor rating is horsepower (H. P.). This refers to power at the shaft under steady state conditions. This number is also unreliable for comparing fan efficiencies.

There is only one method for comparing fan efficiencies and that is CFM/W (Cubic feet of air per minute ÷ watts). At the end of the day all we are concerned with is how much air did we move and how much did it cost to move it.

There are other issues that must be addressed when selecting a fan based on energy consumption.

1) The CFM/W ratings should be provided by an independent test laboratory such as University of Illinois BESS laboratory or Air Movement and Conditioning Association (AMCA). There may be other independent labs doing tests. Before relying on their data consider the source! Is it truly impartial and does it provide quality results?

2) CFM/W ratings should be provided at various 'static pressures', usually from 0 to 0.25" of water column in 0.05" increments. Compare all fans at the same static pressure, usually 0.10".

Fan efficiency ratings³ that are considered acceptable (at 0.10" static pressure) are:

Direct drive fans (<12" diameter)	5-6 CFM/W
Direct drive fans (>12" diameter)	8-15 CFM/W
Direct drive and belt drive fans (30"+ diameter)	15-25 CFM/W

The higher the CFM/W, the more efficient.

3) Also, check to see if the CFM/W rating falls quickly as static pressure increases. This means the fan will perform poorly against wind pressure effects. For example, an energy efficient first stage fan (for example 15 CFM/W) producing 3000 CFM at 0.1" and only 1000 CFM at 0.25" would be very poor as a variable speed fan, and even worse in windy locations. A less efficient fan (for example, 9 CFM/W) may provide 3000 CFM at 0.1" and 2400 at 0.25", and would thus be far more stable. Far more losses and costs can be incurred from inappropriate winter stage 1 and 2 fans performing poorly (improper air quality, excessive fan cycling, etc.). Always use wind hoods on Stage 1 and 2 fans.

4) Fans should be sized first to match the various stages required. Subsequent stages beyond the stage 1 and 2 fans (typically single speed) can and should be more energy efficient as they are not as critical and usually not operated as variable speed.

5) Wind-breaks or hoods will be necessary to ensure optimum air flow. Consider wind hoods on Stage 3 and higher fans in windy areas.

6) Chimney fans can be more efficient than a wall fan. However, the added costs and control issues need to be carefully analyzed before chimney fans are chosen.

The best bet is to have a well-designed, integrated ventilation system, engineered for optimum energy use efficiency.

³ ASAE EP X566 Guidelines for Selection of Energy Efficient Agricultural Ventilation Fans

Light Systems

With high light intensity and energy costs, and much longer photoperiods, the old Edison style incandescent lamp must be relegated to the museum shelves. They are less than 5% efficient at converting energy to light, wasting the remainder as heat energy and have a relatively short rated life (the time at which 50% of the lamps are expected to have failed).

Compact fluorescents (C.F.) have attracted much interest in recent years. They provide good energy efficiency and are easily retrofitted into incandescent fixtures. However, the shorter equipment life and higher cost of replacement C.F. lamps and ballasts compared to 4', T-8 fluorescent tube systems has resulted in higher operating costs and thus reduced cash-flows. So far, CF dimming below 50% of light output has been unreliable. When this is resolved, there will be more opportunity for them.

The new energy efficient standard is the T-8 fluorescent tubes with dimmable electronic ballast, mounted in weatherproof fibreglass or plastic housing with gasketed diffuser. These units are more than four times as efficient as regular life incandescents and the lamps last at least 24 times as long. Refer to Table 5 for relative system efficiencies and lamp life.

Where barn ceiling height exceeds 12', high intensity discharge (HID) fixtures may also be considered. They are easier to install, maintain and require fewer fixtures to provide the same level of light. Types to be considered include:

- X metal halide (nice white light, good colour rendition, and good life)
- X high-pressure sodium (excellent life, the lowest cost, and can be colour corrected for good colour rendition,)

Low-pressure sodium has been used for yard lighting in a few cases, but light quality is poor.

And finally the progress of diode lights has been dramatic. Within a few years, they should be competitively priced and be able to provide good quality, low cost light to smaller defined areas such as creep areas.

Table 5. Relative life and efficiencies of various light sources¹.

Lamp Type	Lamp Size (W)	CRI	Efficiency (Lumens/ W)	Typical Lamp Life (hr)
Incandescent	25 – 200	100	11 - 20	750 - 5,000
Halogen	50 - 150	100	18 - 25	2,000 - 3000
Fluorescent T8	32- 120	75	88	20,000
Fluorescent T5	28- 100	85	104	20,000
Fluorescent T5HO	54 +	85	93	20,000
Compact Fluor.	5 – 50	80 - 90	50 - 80	10,000
Metal Halide	70 – 400	60 - 80	60 - 94	7500 - 10,000
High Pressure Sodium	35 – 400	20 - 80	63 - 125	15,000 - 24,000
LED	1.4	70 - 90	47 - 53	100,000

¹ ASAE IET 433-4 Lighting EP, 2005

VENTILATION & HEATING CONTROLS

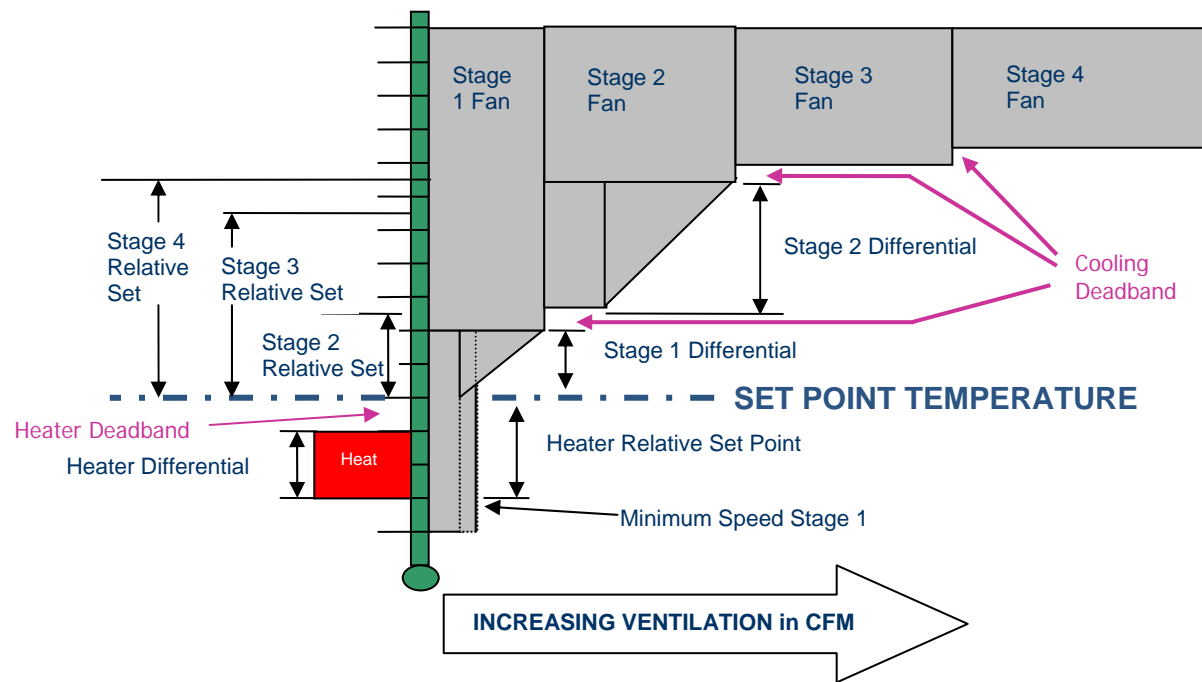
While today's electronic controls are very sophisticated and quite reliable, they are not totally automatic and need to be properly managed. Unfortunately many operators do not take the time to fully understand their controls and often can have settings that automatically waste energy.

The basic operating principle of these controllers is to establish a temperature set point and operate cooling fans at various room temperature values above that reference point and similarly operate a heating system at room temperature values below that same reference point. While the principle is straight forward, it is easy to program inappropriate start and stop temperature values which cause energy waste.

A classic example of heat waste is allowing the heating equipment to run sufficiently long to raise the actual room temperature up to the reference or set point temperature prior to shutting the heater off. While this sounds like a logical thing to do, the problem is that there is a considerable lag time in the temperature sensor responding to any change to which it is exposed. Complicating the matter is the fact that we must size the heating equipment for the coldest weather expected and as such is over sized for the majority of the heating season. Thus the heating equipment is putting a lot of heat energy into the room environment and the actual temperature will usually continue to climb at least 0.3C (0.5F) after the sensor calls for heat shut off. If this additional temperature rise (overshoot) brings the room above the set point temperature, the stage 1 fans simply speed up as programmed and extract the heat just purchased. Air quality may be better but heat is wasted. Additionally, the pigs are being subjected to an unwarranted temperature fluctuation. The simple correction is to ensure that the heating equipment is programmed to shut off at least 0.3C (0.5F) below the set point temperature.

A second energy waster is fan temperature settings that touch or even overlap. For example, the second variable speed fan starts at a temperature lower than the full speed temperature setting for the first stage variable speed fan. In this case, electrical energy is being used to operate two fans when generally only one was necessary. Another common setting that wastes energy is having the stage 2 or stage 3 fan start at the exact same temperature as the previous variable speed stage reaches full speed. In this case, the controller does not give the previous fan any time to run at full speed on its own to determine if it can maintain the desired room conditions without assistance. Typically the additional fan only runs for a brief period of time and after lowering the room temperature a half to one degree shuts back off. Not only is some extra energy used, we have exposed the pigs to another temperature fluctuation that often was unnecessary. The proper strategy is to build in a 0.3C (0.5F) cooling deadband between each fan stage to allow that level of fan power a chance to maintain the room conditions. If it is not adequate, the room temperature will slowly climb that part of a degree and then additional fan power will be activated.

Figure 1. Diagram showing typical ventilation control strategy.



Lastly, I often see the total ventilation bandwidth set too narrow, such that all of the ventilation fan power is operating far sooner than usually necessary. For most swine environments, the total temperature bandwidth between minimum and maximum ventilation should be in the range of 5C to 7C (9F – 11F). Tighter bandwidths not only waste energy, but again expose the pigs to a rapidly changing temperature and potential drafts that are often associated with extra ventilation.

HEAT RECOVERY

As we all know, a lot of heat energy is expelled continuously through the exhaust fans on every livestock facility. Fairly simple heat exchangers can recover 25% to 50% of this heat energy. However, there are two big problems with most heat exchangers. They plug up very quickly and require constant cleaning. Secondly, they only recover low grade heat. That is, they simply pre-warm the incoming fresh air so that it is warmer than outside but still considerably cooler than the room temperature. With an intake fan blowing this air into the room, it can still create drafty conditions for the pigs. Thus a secondary air distribution system is required or it needs to be ducted into the main air inlet system (if one exists). Again heat exchangers are often better suited to swine enterprises where the reclaimed heat can be directed to a central hallway that provides the winter fresh air supply to a number of rooms.

In the past most of the commercial heat exchangers were relatively small plate to plate units designed to provide some recapture of heat back into the same air space as it was exhausting from. While this concept still works for a design where the reclaimed heat is ducted to a

common hallway, the multiple heat exchangers being employed increases capital cost and maintenance. Two locally based innovators are working on tube and shell type heat exchanger designs that may not be quite as efficient as the plate to plate style but are far easier to clean and maintain. Additionally they are sizing the units larger to be more practical for many of today's room populations and allow the use of variable speed fans.

Several innovators over the years have developed various forms of larger exchangers that take air from a number of rooms and deliver the incoming warmed air back to a common hallway. There can be significant capital savings in custom building a larger exchanger and utilizing a single intake fan to pull the fresh outside air through the exchanger tubes. In fact some designs even use a common fan to pull the minimum exhaust air from several rooms. The most common type of multiple room heat exchanger in the past was a side hallway design with all of the exhaust fans dumping the warm dirty air into this hallway and fresh outside air being pulled through either a full wall plate type exchanger or a number of air tubes suspended through the length of the hallway.

Air Works is a U.S. based company that offers a custom designed ventilation system that includes a very large tube and shell heat exchanger tied into pit ventilation for pigs. This company has several of these systems installed here in SW Ontario. There are definitely some increased energy efficiencies with these large scale systems that can make them attractive for energy conscious producers. A lot fewer exhaust fans are employed and those that are used tend to be larger and more energy efficient. However, these multiple room systems do increase the complexity of controlling the air quality in each individual room and thus require more management on a regular basis.

As the cost of energy continues to rise, I do believe that we will see an increased use of heat recovery and central hallway systems for winter air supply.

ALTERNATIVE FUELS

There has been a lot of interest in alternative fuels including biomass and even coal. There are a number of issues that need to be clearly identified and calculated into the equation prior to making an investment in an alternative fuel system:

- Is the cost of the new fuel going to be stable at least until the pay off of capital is complete? For example, a corn burner may look great with historically low corn prices, but if they rise to profitable levels in the next few months, how will the payback look then?
- Will the system integrate easily with my facility? For example, if the system uses hot water and your facility is completely forced hot air, then costly heat system delivery changes will also be required.
- Labour is also a major issue that many people overlook. Biomass systems will require much more effort to keep them going. If the fire goes out at 2:00 a.m., someone has to get out there and restart it. Clinkers, a hard substance left behind as part of the biomass combustion process, will need to be dealt with.

- Ash disposal; for large burners, ash removal and disposal can create serious problems due to the enormous volumes created.

RENEWABLE ENERGY: SOLAR & WIND ENERGY

If we recall the energy crisis of the early 80's, we saw the introduction of a number of alternate energy technologies. These included a whole range of heat exchangers, heat pumps and solar energy collectors. None of these technologies lasted longer than about 10 years for a couple of reasons. Generally speaking, the cost recovery for these systems was about neutral (i.e. the system wore out by the time the energy recovery had paid for the installation). Frequent cleaning and other maintenance issues plagued many of these units and they were quickly abandoned.

Now that energy costs are starting to take another forward leap, it may be time to revisit these technologies and see if we can utilize them more efficiently than was the case 20 years ago.

Last winter I took a trip into Quebec to look at a rather simple solar collector concept being employed on a number of livestock buildings in that province. This product, called SolAgra is simply perforated black painted metal siding that is used as a flat plate solar collector and tied into the fresh air intake system for the building. The perforations (created by surface indentations) are custom sized to allow between 1 and 20 CFM per square foot of fresh air to enter parallel to the back side of the metal surface such that the heat gain from the sun is transferred into the air stream.

In its simplest form, the SolAgra product is used to create the fresh air intake hood (installed with the metal ribs running either horizontally or vertically) for a typical continuous baffle board air inlet. With the addition of a winter closure board at the bottom of the intake hood, all of the cold weather fresh air enters through the perforated metal hood covering. Providing the sun is shining on the metal hood, a significant heat rise can be achieved for the incoming air. This temperature lift can be significant and makes the ventilation air drier and a more efficient moisture collector as soon as it enters the building. Secondly, less supplemental heat is required to complete the temperature lift to the desired room temperature.

However a large percentage of our swine enterprises utilize the entire attic space as the fresh air plenum. For this heat collection system to be effective it would be necessary to ensure the entire attic was well insulated to not lose this heat prior to it being introduced to the various rooms. This type of system is better suited for a ventilation system which utilizes a central hallway for its winter air supply to a number of rooms. This can work well with the entire end wall of the building being utilized as a solar collector.

Of course, the biggest downside with any solar energy source is that it only works when the sun shines on that particular portion of the building. If we have a bright sunny winter, there is a lot of heat energy to be gained during a portion of each day. However, this winter has not been particularly sunny and as such, limited energy was collected. Storing the sun's energy for later use is the other main downfall of many renewable; or so called, "green" energies.

Simple, economical energy storage has yet to be developed and until then will limit the wide spread use of this type of technology.

On the plus side, SolAgra metal siding is extremely simple with little or no maintenance and thus over the long run should be a net energy saver. Currently, due to patent rights, there is only one source for this product which makes it a seller's market. However, the good news is that Natural Resources Canada offers a grant of 25% for the purchase and installation of this type of system through their Renewable Energy Deployment Initiative.

Wind energy is highly unlikely to be a feasible alternative for most swine enterprises due to the extremely high capital costs involved with a wind turbine and generator. However, small systems are starting to appear in the market place and thus should not be entirely ruled out in the longer term.

CONCLUSIONS

Optimizing your facilities for energy efficiency will have a number of benefits; to your energy bills, pig performance, and overall indoor air quality. Developing an appropriate efficiency strategy will vary considerably from farm to farm and even barn to barn based on the existing situation and the cost analysis of any improvement or over-all system change.

