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Facing the New Reality

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of the
LONDON SWINE CONFERENCE

Facing the New Reality

Edited by
J.M. Murphy and C.F.M. de Lange

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Proceedings of the London Swine Conference
Facing the New Reality

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CONTENTS

Chair's Message	v
Steering Committee.....	vii
Sponsors	viii

THE NEW REALITY 1

An Industry in Change	3
<i>Ben Woolley</i>	
Is There an 'Optimum' Production System?	7
<i>Michael Brumm</i>	

OPTIMIZING REPRODUCTION IN A NEW ENVIRONMENT 15

Balancing Sow and Piglet Welfare with Production Efficiency	17
<i>Sandra Edwards</i>	
New Opportunities for Reproductive Management	31
<i>William Flowers</i>	

WHAT DOES THE FUTURE HOLD? 43

Impacts on Further Growth of the North American Pork Industry	45
<i>John Lawrence</i>	
MISSION 2050 - Research and Industry Infrastructure in the Year 2050	55
<i>Vern Osborne</i>	

DEALING WITH OLD AND NEW DISEASE CHALLENGES 61

Porcine Reproductive and Respiratory Syndrome Virus (PRRSV): The Disease that Keeps Bugging Us.....	63
<i>Jeff Zimmerman</i>	
Control of Salmonella in the Pork Production Chain	73
<i>Julie Funk</i>	

BREAK-OUT SESSIONS..... 79

Livestock Border Closure Contingency Plan	81
<i>Deborah Stark</i>	
Preparing for a Border Closure.....	85
<i>Clare Schlegel</i>	
Border Closure: Effects on the Ontario Feed Industry.....	87
<i>Dan Ganesh</i>	
Managing Pig Flow – Considerations as a Buyer of Weaned Pigs	95
<i>Michael Brumm</i>	
Optimum Pig Flows	99
<i>Ben Woolley</i>	
Insurance Based Risk Management for Swine Facilities	101
<i>Randy Drysdale</i>	
Risk Management for Farms	105
<i>Paul Wigood</i>	
 Using Dried Distillers Grains with Solubles (DDGS) in Swine Diets	 107
<i>Malachy Young</i>	
Canadian Experience with Feeding DDGS.....	115
<i>Phil McEwen</i>	
Canadian Experience with Feeding DDGS.....	121
<i>Andrew Pharazyn</i>	
Fire Disaster Recovery: Producer and Veterinary Perspectives.....	131
<i>Paul Morris</i>	
Pulling the Pin on Disease	141
<i>Sue Burlatschenko</i>	
On-Farm Animal Welfare Audits.....	145
<i>Sandra Edwards</i>	
Developing the Animal Care Assessment	157
<i>Catherine Scovil</i>	
 Optimum Solutions for Grower-Finisher Pigs.....	 161
<i>Neil Ferguson</i>	
Nutrition Solutions for Grower-Finisher Pigs.....	167
<i>Bruno Marty</i>	
Alternative Sources of Energy – On-Farm Options	171
<i>Steve Clarke</i>	
Challenges in the Anaerobic Digestion of Hog Manure	177
<i>Marcel Stadelmann, Benjamin Strehler, Cigdem Eskicioglu, and Kevin Kennedy</i>	
Applying Reproductive Technologies in Practice	185
<i>William Flowers</i>	
Quality Control of Extended Boar Semen	195
<i>Mario Baracaldo and Jim Ward</i>	

CHAIR'S MESSAGE

Welcome to the 8th London Swine Conference!

Since it began, the objectives of this conference have been “to provide a platform to accelerate the implementation of new technologies in commercial pork production in Ontario and to facilitate the exchange of ideas within the swine industry”. This year’s theme, “Facing a New Reality”, acknowledges the challenges facing the Canadian pork sector.

Considering that planning for the program begins many months in advance of the conference itself, the Technical Committee has done a superb job of identifying the issues and in recruiting an international panel of experts to speak to them.

The economics of pork production is in sharp focus, globally and right down at the production level. Changing production practices, whether in search of efficiency or in response to social pressures, are addressed. Production management, nutrition, reproduction, welfare, and health are all keys to success, and new ideas and practices in all of these areas will be presented and discussed.

Effective decision making is difficult at the best of times but, especially when facing a challenge, it requires clear understanding of the challenges and reliable information about opportunities and options. Discussion and reflection then often illuminate the best path forward. This conference aims to improve understanding, highlight opportunities and options, and to provide a forum for discussion and reflection. With our line-up of speakers and topics, the stage is well set for another successful conference for 2008.

An initiative of Ontario Pork, the University of Guelph, and the Ontario Ministry of Agriculture, Food and Rural Affairs, this conference is now established as a leading Canadian event in the pork industry. The success of the conference is the direct result of the hard work of a team of dedicated people working over the previous year to pull all of the components together, the generous support of our industry partners and sponsors, the expertise and contributions of our speakers, and not least the enthusiastic participation of the people in the industry in attending, questioning, discussing, moderating, and networking. Sincere thanks to all.

Enjoy the conference!

Jaydee Smith
Chair, Steering Committee
2008 London Swine Conference

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THE NEW REALITY

AN INDUSTRY IN CHANGE

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The difficult part of writing an economic paper for a conference more than a month away is that things change so fast that by the time the conference actually happens, the paper is probably outdated.

On the other hand, my livelihood fortunately does not depend on the predictions being entirely accurate, so I can say what I believe to be true without having to worry too much whether all the prognostications will be fully vindicated!

You will also notice if you take the time to read this, that it is quite different from my actual presentation. In this, I am focusing more on where we are going, whereas in my presentation, I focus more on what got us here. The reason for this is that the paper is more a reference tool to use to make decisions as opposed to me blabbing on about things we need to do to change in the industry as a whole. If you want a copy of the presentation, I will gladly send it to you.

For most producers wrestling with the current crisis, it seems as if there is no future for those who have invested their lives, not to mention their money, in facilities.

The industry has been hit with a series of economic events that have seriously damaged our ability to compete in the international markets.

The strength of the Canadian dollar, along with the weakness of the US dollar, have not only made it difficult to compete for valuable export markets such as Japan and Asia, but have also rendered the industry in Canada higher cost than our US counterparts.

The valuable export market for weaned pigs and feeder pigs to the US is finding it much more difficult to extract profit when the product has been so badly devalued.

In addition to this, packers in Canada have been exposed as high cost and rather inefficient when put next to their US counterparts. If they had been able to maintain premium markets during this time, they would be in much better shape. However, some resorted to dumping product on the market at below market values and so got a reputation of being a low cost producer rather than a value added producer. This was okay with the weak dollar, but when it strengthened relative to the US currency, it exposed this as a short-sighted strategy.

For individual farmers this can be a pretty demoralizing time. Many have spent years building a business they are proud of. Having to face decisions to shut down these businesses are very difficult to make, and many will fight too long in an attempt to stave off the inevitable.

It is essential to try to take an objective approach to these decisions and to try to detach oneself from the emotion. This can be very difficult when family members may have a different opinion. It is absolutely essential to recognize this and not to get short tempered with family members who are trying to help. Remember that they are feeling the stress as well.

The main decision one needs to face is whether the business can be competitive long term, or whether there is some value added market that can be accessed that allow you to continue to produce but get more from your final product. Pretty obvious stuff; but not always at the forefront of people's minds when they are considering what to do with their businesses.

The key to making decisions is going to have three aspects to it:

- Can I survive this current crisis without unduly risking all my assets?
- Will I be in good enough shape to take advantage of the markets when they turn, and will the upside be long and strong enough to regain and advance my equity position?
- Will I be able to refine my business to compete?

Unlike most people in the Canadian industry, I see the industry in a position where once the current crisis is past, there may well be a period that will be one of the most profitable we have faced in a long time, if not ever. However it looks likely that most of the benefit will be for those established in the US market in some way.

At the time of writing, there are several factors that are pointing me to this decision:

- Cull sow slaughter in North America is at an all-time high and the packing industry is not able to actually keep up with the number of sows going to market.
- Farmers in the US who built their units in the late seventies and early eighties are facing losing most of the equity they have built up in the past three years. Many are nearing retirement and do not want to go through another downturn in the industry. They are therefore deciding to close their units down rather than embarking on costly renovations needed.
- We all know the Canadian herd reduction is in full swing. This will decrease the number of animals going to the US for finishing.
- Grain is over priced. The increase has been driven by the shortage of wheat and the ethanol subsidy. There appears to be adequate harvests in Australia and South America; CRP ground will be in production in Europe in 2008; there may be an announcement in the US in the near future that either the ethanol subsidy will be decreased or repealed, or that the import duty on ethanol will be dropped. A half decent harvest in the US and Canada will ensure adequate supplies of grain in the fall and prices will drop accordingly.

You will notice, as I said, that most of this pertains to the US market.

I still do not think it will be as profitable in Canada as in the US as we still have the constraint of the strength of our dollar and the problems in our packing industry.

In addition, if the futures remain as strong as they are at the time of writing, we might see some curtailment in the liquidation which will decrease the strength of the industry revival.

Producers therefore need to decide how to position themselves to take advantage of this and not remain chained to the rather archaic system we have saddled ourselves with in Canada. (More on that in my presentation).

It serves no good to assign blame to individuals for the current situation. However everyone needs to recognize the need for change. Protecting people's turf at the expense of the betterment of the industry is not only selfish and unhelpful, but also immoral in my mind.

Organizations supported by the industry are there to promote and assist the industry, not to make an easy life for the people who work there. Directors especially are essentially public servants, and should make decisions accordingly.

What do we need to get there?

- We need industry organizations that work hard to identify and promote new value added markets.
- We need to become more competitive as an industry. There are plenty of ways this can be achieved which I will go into in more detail in the presentation.
- We need to be better at risk management.
- All parts of our industry and those servicing the industry need to understand that we have to drive cost out of the system. Feed manufacturers, veterinarians, transporters, drug companies and equipment marketers all need to understand that they will have to survive on lower margins if the industry they serve is to survive.
- We need government to remove the barriers that serve only to decrease the competitiveness of our industry. These include:
 - Not supporting industries such as ethanol that add cost to food production without assisting producers as well.
 - Not being bullied by the supply-managed agriculture sectors at the WTO negotiations. The beef and pork industries produce far more exports than all the supply-managed industries combined and so are far more affected by trade distortions caused by supporting uncompetitive industries.
 - Helping agriculture by allowing producers to recruit staff from overseas instead of throwing every possible encumbrance in the way.

Lastly a word about the packing industry in Canada:

- There is not a lot of point in supporting an industry that cannot compete and repeatedly requires help to survive.
- It needs to change.
- Obviously plants need to become more efficient or carve out a market for themselves that adds enough value to allow them to thrive. The problem with this strategy is that if a market adds enough value to be attractive, no sooner are you servicing it than

someone else comes along to service it at lower cost or better. Pretty soon it becomes the norm and you have to find another niche for your product.

The Canadian industry has not done a good job of this. When the Canadian dollar was relatively weak, some in the industry got complacent, as it was easy to export and compete with higher priced product from other producing countries.

Therefore the packing plants need to work hard to become more efficient as well as finding new value-added markets.

In conclusion, we need to get better at what we do. We need to figure out ways to cut costs and add value to what we are producing.

This will require us to basically “reinvent” our industry in order to compete on the world stage.

There will be opportunities for those positioned to take them both in Canada and in the US.

For those unwilling or unable to change, both in production and in processing and ancillary industries, there is little hope of being able to compete.

This is a new world we are in and we need to adapt.

IS THERE AN ‘OPTIMUM’ PRODUCTION SYSTEM?

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INTRODUCTION

Increasingly, the US and Canadian pork production industries are linked, both because of the linkages of costs for such inputs as feed grains and because of the large numbers of Canadian weaned pigs transported to US sites for growth to slaughter. Many Canadians have even taken to retaining ownership of weaned pigs in US facilities. This suggests that an ‘optimum’ production system now must include management of financial risks that include currency exchange rates.

As North American production reacts to the latest round of very high priced feed grains and a very weak US dollar, there are expectations that Canadian producers will be the ones who reduce their production capacity first. In the next round of profitable pork production, what will ‘optimum’ production systems have in common?

IS THERE AN OPTIMUM SYSTEM FOR NORTH AMERICA?

The quick and easy answer to this question is no – there is no single optimum production system. The more appropriate question is – what do ‘optimum’ systems have in common? If we can answer this question, even partially, we then have to look at what direction the pork industry in North America is heading.

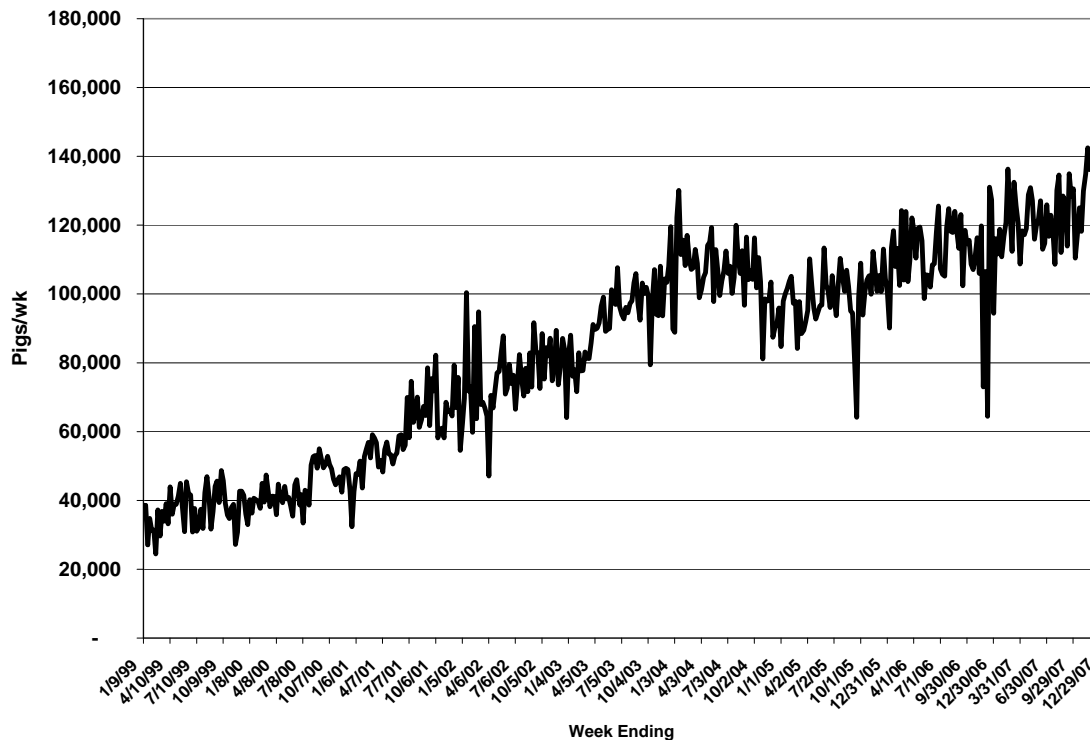
The North American System of Production

Notice that I begin by saying the pork industry in North America, not the industry in Canada or the industry in the United States. This past year has demonstrated to Canadian producers with harsh economic reality the complete linkages of the US and Canadian industries and the risks currency exchange rates add to this linkage. As market hog prices sank in response to record supplies in late fall and early winter of 2007-08, feed grain prices in both countries soared in response to increased demand. This demand is being driven by the large inventory of livestock in the US (feedlot cattle, pork and poultry), the rapid growth of the bio-fuels segment of the economy and the weak US dollar which is causing a very large export demand for US sourced feed grains.

Canadian producers have built an industry that is increasingly linked to US production sites. Imports of Canadian born feeder pigs (defined by USDA as live pigs weighing <55 kg) have steadily increased in the past 9 years, reaching record numbers in 2007 (Figure 1). In 2007, 6.47 million feeder pigs entered US production systems from Canada. At 22 weaned pigs per

sow per year, this represents the output of 294,000 females. Given that the October 1, 2007 sows and bred gilt inventory in Canada was 1,560,000 head, export of feeder pigs to US systems in 2007 accounted for almost 19% of all pigs weaned in Canada.

Figure 1. Weekly US imports of Canadian feeder pigs .
(http://www.ams.usda.gov/mnreports/WA_LS637.TXT)



A combination of demand by US producers for feeder pigs and economic conditions in Canada is the driver of this importation demand. Demand in the US is being fueled further by the regulatory climate facing owners considering construction of new farrowing and growing facilities and the continued evolution of the US industry.

In many instances, wean-finish barns are being constructed by former farrow-finish producers who have sold off their breeding herd, but want to continue to have pigs as part of their agricultural production system, in part because swine manure is viewed as a valuable contributor to corn and soybean cropping systems.

For many finishers of pigs, the opportunity to participate as owners in large farrowing sites is limited, or the finisher perceives the risks as too large, or the finishers long term plan is to exit the swine industry at a future date. Thus, a demand was created for feeder pigs that are not tied to ownership of the breeding herd that generated the pigs.

By sourcing pigs from Canadian producers, these Midwest US producers avoid the long term financial commitment associated with ownership of sows in a production network while retaining pork production as a contributor to their economic well-being.

Recently, US cash grain farmers have been investing in pork production facilities with the intent of having access to large amounts of manure as a fertilizer resource. In many cases, the cash grain farmer owns the facility with a management firm hired to coordinate pig ownership and labor for daily pig care activities.

It is interesting to note how the changing regulatory process has directed the evolution of the production process. Over the past 10-15 years, regulation of pork production sites via zoning ordinances and pollution control permitting has been touted by opponents as one way that large production systems would be limited in scope. The regulatory process has imposed large costs to production systems of all sizes. Not only is the process of siting and constructing new facilities more complicated, but the record keeping requirements and the risks of non-compliance with pollution control permits are an on-going expense. The net result is that many small and even medium size operations in both Canada and the US have chosen to either not expand production or to quit production. The regulatory process has in fact favored large production sites/systems due to the ability to spread the regulatory costs over large numbers of pigs and the ability to be large enough to have one or more employees dedicated to meeting the regulatory paperwork and filings requirements.

In Iowa and southern Minnesota wean-finish sites are very often sized for capacities of 2400 pigs. This size is chosen in that it is just small enough to not require application for a state operating permit but is large enough to capture some of the economies of scale.

On the economic side, the exchange rate for the Canadian-US dollar was an early driving force linking Canadian and US production systems. In the late 1990's and early in this century, the Canadian dollar traded as low as \$.67US per \$1CA. This meant that producers selling weaned pigs delivered to US buyers at \$32/pig were receiving \$47.75CA for these pigs, a strong incentive to expand farrowing. At the end of 2007, the exchange rate was \$.98US per \$1CA. The same \$32 delivered price now returned only \$32.65CA, a 32% drop in income just due to the change in exchange rate. On the other hand, the US producer pays \$32US at all times since the Canadian pigs have been a relatively small segment of the US total industry, meaning they don't warrant a major price differential.

What Will the Next Generation of Production Systems Look Like?

While current economic conditions don't support investment in production facilities, at some point reinvestment in production facilities will occur. This reinvestment will be done with an eye towards producing pigs in an 'optimum' system. These 'optimum' systems will have production goals that were thought to be unattainable a few years ago (Table 1).

The question then becomes - how do production systems attain these goals? The answer lies in how these systems apply the resources of females, facilities, people and dollars to the production process.

Table 1. Attainable production goals in 2008.

<ul style="list-style-type: none">• 24 pigs sold to slaughter per female/year• 6500 pounds sold to slaughter/female/yr• 1.7 lb/d daily gain wean-finish• >75 pounds of gain per ft² of pen space wean-finish/yr• <3.0 whole herd feed conversion farrow-finish• <2.55 feed conversion wean-finish on mash diets with minimal added fat• <4% post weaning mortality• <4% lights and culls at slaughter
--

In the production process, the key component is people. While the industry talks about the ‘science’ of pork production, the best production systems put in place people who practice the ‘husbandry’ of pork production. Successful production systems have procedures in place to not only hire the right people, but they also spend considerable amounts of time and money on training and assessing these people.

The second component of successful production systems is the matching of facilities with the realities of pig flow. In the case of facilities, as discussed earlier, the trend in Iowa and Southern Minnesota (which have 40% of the US growing pig inventory) is to construct wean-finish facilities sized for 2400 pigs. Wean-finish facilities are now costing over \$250/pig space when you add up the site development fees (site preparation, well, road, electricity, etc.), permitting fees (zoning hearings, permit application fees, etc.) and construction costs. The larger the facility, the lower the per pig costs of site development and permitting as these tend to be the same total dollars regardless of facility size. On the other hand, no state construction or operating permits are necessary for most sites as long as they contain fewer than 2500 pigs.

At one time there was considerable debate regarding the pros and cons of using nurseries and finishers versus using wean-finish facilities. The industry has made the clear choice with wean-finish as the preferred housing option. This choice has been driven in large part by lenders.

If lenders loan money to producers for construction of swine nurseries and finishers, they feel they have increased risks since there currently is very limited demand for swine nurseries. That is, if the lender is forced to assume a swine facility loan for a swine nursery, what are the options to generate enough monies to pay off the loan? Is there someone willing to place pigs in the nursery unit, either as a buyer of the facility or as a contract user of the facility? On the other hand, if the lender has to assume a swine facility loan for a wean-finish facility, the option to utilize the facility as a contract finisher is very attractive. The demand for contract finishing space in the upper Midwest remains very strong. Cash income is readily generated to pay off the debt.

Because of cost considerations, wean-finish barns are routinely overstocked, most often as a double-stock. The extra pigs are removed at 5-8 weeks post weaning. While different economic models exist, a common estimate is that double-stocking lowers the per pig facility

expense by \$3/pig or more versus single stocking. This means that the 2400 head wean-finish facility must source approximately 4800 pigs at the time of pig placement. To minimize age variation and the management issues associated with this variation, including ventilation and weaned pig diet budgeting, sites most often want to have the full complement of pigs delivered in less than a 2 week period. Minimizing age spread due to weaning to less than 2 weeks also limits the duration of marketing to slaughter, maximizing the utilization of the facility for gain.

This need for large numbers of weaned pigs with minimal variation in age is one of the driving forces in the sizing of farrowing sites. To deliver 4800 weaned pigs within 2 weeks to a wean-finish site requires pigs from 516 litters at 9.3 pigs weaned/litter. To get this many litters, one can either co-mingle pigs from a number of farrowing sites, or have a farrowing site that farrows 260 litters per week. In order to minimize health risks from PRRSV, PCVAD, swine influenza, etc. production systems are choosing to not co-mingle pigs whenever possible. This means the farrowing site needs to have approximately 6000 females, not counting replacement gilts. It turns out that a common size many systems are considering is 6500 female places which includes room for the replacement gilt inventory.

Batch farrowing is an option to these very large farrowing sites. Four 1500+ female sites that each farrow 260 females/week on a 4 week rotation achieve similar weaned pig numbers. Weaned pigs at any wean-finish site are limited to being sourced from 2 farrowing sites. As most large wean-finish facilities are comprised of 2 rooms, all pigs within one room are often from a single farrowing site, reducing the co-mingling of sources effect. Of course, batch farrowing carries with it the scheduling difficulties of females (re)cycling off-schedule, etc. and work loads that are very intense for 2 weeks and then relatively lax for 2 weeks. At least one production system in the US with a number of farrowing sites located relatively nearby rotates specialized production staff such as farrowing and breeding technicians between 4 sites on a weekly basis to address this challenge.

This evolution in size and scale is not recent (Key and McBride, 2007). In the late 1970's and early 1980's a common production system was the 100 sow farrow-finish producer. In this system, the basic unit of production was the 20 crate farrowing house. Often times, there was a 180 pig nursery associated with the farrowing house. The move to confinement finishing meant the addition of a 4-500 head continuous flow grower-finisher.

In many instances, in the late 1980's and early 1990's, the sows were sold with the producer seeking a source of weaned or feeder pigs to continue in pork production with existing facilities. As the benefits of all-in/all-out pig flow became recognized, this meant sourcing 4-500 pigs with minimal age variation, preferably from a single source to minimize the risks of diseases due to co-mingling. This meant that the preferred sources for pigs were sites that farrowed 50 or more litters per week. This translated into farrowing sites with approximately 1200 females farrowing weekly, or sites with 350 females batch farrowing once every 4 weeks.

In the mid 90's, the common investment in finishing facilities was a 1000 head facility, meaning it took 2 weeks to fill with weaned pigs from a 1250 female site or from 2 350 sow

sites batch farrowing. This makes it very clear that the evolution of swine production facilities, especially as related to size, is clearly tied to the health benefits of all-in/all-out flows and minimal age differences. It is also clear that the sizes of today's production facilities are a result of the first confinement facilities built to accommodate pig flows from 20-crate farrowing facilities.

Because of the large investments associated with both farrowing and growing pig sites, the swine industry has started to focus more attention to the impact of variation in pig numbers (as reflected in pigs weaned/week) on costs of production. It is one thing to plan production flows with spreadsheets and financial budgets for 260 litters of 9.3 pigs per litter per week. The reality is that pork production is a biological process with considerable potential for variation in the biological process. The 'optimal' production system puts in place people and production practices that minimize variation. These practices include information systems that serve not only to document what has happened but to also be useful in predicting future production variations.

The 'optimum' production system does not make decisions in a vacuum. The successful production system utilizes a team of advisors. Note that I said a team, not a series of individual advisors. It is important that the animal health advisor sit at the same table as the financial advisor, along with the legal advisor, nutritionist, etc. The complex interactions between production, finances and legal requirements means that all members of the team need to be informed about the impact their recommendation(s) have on other team member's recommendations. All too often an advisor or consultant is brought into a production system or site and is forced to make a recommendation without having full knowledge of the limits to implementation of the recommendation or causes for the situation. Information sharing between members of the advisory team is critical to the success of the swine enterprise.

Also note that as public support for University and USDA research and extension outreach decreases in the US (Fuglie and Heisey, 2007), with a similar decline in related services for Canadian producers, access to new technology and information will become fee based. Increasingly producers will have to pay an advisor for information that is relative to a production need whereas this information was publicly available in the past via university research reports and extension specialists. Look for this trend of less public access to information to continue as politicians wrestle with budget deficits and an agricultural production system that is an ever smaller segment of the Canadian and US economy. This limit to public funding of information ultimately benefits those production systems which access information. This information access may be thru investment in specialized research facilities or it may be thru information sharing in peer-to-peer discussion groups.

CONCLUSIONS

The many factors that go into an 'optimum' production system often are only slightly related to individual pig performance. The economics of facility and site sizes, when combined with the growing number of regulatory requirements has meant that the 'optimum' production system is much larger than in the past. While production systems have added science-based

information to their decision process, quality people involved in the daily care of pigs remains a key component of successful production.

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OPTIMIZING REPRODUCTION IN A NEW ENVIRONMENT

BALANCING SOW AND PIGLET WELFARE WITH PRODUCTION EFFICIENCY

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ABSTRACT

The close confinement of sows in barren environmental conditions gives rise to major public concern for their welfare. Such concern has resulted in EU legislation to ban individual confinement systems for the majority of gestation, and strong pressures to find alternatives to the farrowing crate for lactating sows. Many alternative loose housing systems for dry sows exist, and have been in widespread use for a number of years. They have the potential to deliver both higher welfare and good reproductive performance, but careful attention to feeding and management to prevent social stress is critical to success. Adoption of alternative non-confinement systems for farrowing and lactation is more problematic. Despite their routine use in some EU countries at the current time, systems which guarantee good piglet survival under large-scale indoor production conditions have yet to be commercially proven. It is likely that changes to both genetics and management will be necessary to make such systems function in an acceptable commercial way.

THE CURRENT STATUS OF SOW WELFARE LEGISLATION IN THE EU

Amongst the many issues in the debate on farm animal welfare, it is those which involve the close confinement of animals in barren environments which have given rise to the greatest public concern. Thus, the keeping of laying hens in battery cages, the raising of veal calves in individual crates and the use of gestation stalls and farrowing crates for sows have been the first targets for campaigns by welfare pressure groups, and the subject of responsive legislation. Within the EU, the first restrictions on sow housing systems were specified in Directive 91/630/EEC, which required the phasing out of tether systems by 2006. Stall systems for gestating sows, while still permitted under this 1991 Directive, were acknowledged to pose a number of challenges to sow welfare and were made a key subject in a detailed review of pig welfare by an EU expert working group (Scientific Veterinary Committee, 1997). As a result of the conclusions from this review, further restrictions were introduced in an amendment to the Directive in 2001 (Directive 2001/88/EC) which requires phasing out of the use of gestation stalls, except for the first 4 weeks of pregnancy, by 2013. Several countries (including Norway, Sweden, Switzerland and UK) have unilaterally implemented a ban on all individual confinement systems for dry sows before this date. The target of animal welfare pressure groups is now the farrowing crate, and the 2001 Directive amendment specifically requested a scientific review of this subject which has recently been delivered (EFSA, 2007). Whilst no EU-wide legislation appears imminent regarding this

system, some countries (including Norway, Sweden and Switzerland) have again taken unilateral action to restrict their use, and public pressure in many other countries to find an alternative remains high.

THE WELFARE ISSUES

The welfare aspects which have raised concerns about the close confinement of sows can be divided into physical and behavioural issues. Physical concerns arise from the consequences of lack of exercise for cardiovascular fitness (Marchant et al., 1997) and for bone strength and muscle mass (Marchant and Broom, 1996), potentially giving rise to leg weakness and lameness (Barnett et al., 2001). Lack of activity, in combination with inability to separate the lying and excretory areas, has also been blamed for a higher prevalence of cystitis in confined sows (Madec, 1984). However, whilst these health issues are of importance to producers, it is the behavioural issues which have attracted most attention from the public, with the high level of stereotyped behaviours often seen in confined dry sows providing a highly visual focus for concern. Although initially attributed to the stress of close confinement and the boredom engendered by barren environments, subsequent work clearly demonstrated that the occurrence of these abnormal oral behaviours was much more closely linked to feeding than to housing system (Terlouw et al., 1991). Studies have demonstrated that pregnant sows experience chronic hunger because the level of concentrated feed necessary for maintenance of good health and performance is insufficient to induce feelings of satiety. Expression of the resultant feeding motivation is frustrated in the absence of a foraging substrate, such as soil or bedding, giving rise to channeling of behaviour into stereotype development in restrictive housing conditions. Thus, whilst the housing system is not, in itself, the cause of the abnormal behaviour it is a significant contributory factor to its expression.

For the farrowing sow, the most significant welfare issues associated with confinement again result from the frustration of strongly motivated behaviours by a restrictive environment, although the motivation in question is different. Under natural conditions, the sow seeks a nest site and then builds a nest shortly prior to farrowing in order to provide an appropriate environment to maximize survival of her newborn piglets (Wechsler and Weber, 2007). Such is the importance of this behaviour in an evolutionary context that it has become genetically programmed, and the hormonal state shortly prior to farrowing will induce strong nest building motivation, even when its original function is unnecessary because of human provision of an optimal piglet environment. Prevention of the expression of pre-nesting locomotion and nest building behaviour at this time, through confinement and lack of substrate, results in a measurable heart rate and stress hormone response, in addition to abnormal behaviours, indicating impaired welfare state (Lawrence et al., 1994; Jarvis et al., 2002; Damm et al., 2003). The farrowing crate may also impose other welfare challenges for the sow in later lactation, when she would normally begin the process of gradual weaning by withdrawing from the piglets for increasing periods of time. Enforced proximity and being subject to the demands of increasingly persistent piglets has been associated with elevated levels of cortisol in crated gilts in later lactation (Cronin et al., 1991; Jarvis et al., 2006).

In the case of the farrowing and lactation period, however, the welfare issues do not just relate to the sow. The original reasons for adoption of the farrowing crate were to reduce mortality of neonatal piglets by the control of sow movements which might cause crushing, and by the ability to increase environmental temperature controls and human inputs at a time when these interventions can significantly enhance survival (English and Edwards, 1996). It is the potential for conflict between the welfare needs of the sow and her piglets which has made the issue of the farrowing crate so problematic.

THE NON-CONFINEMENT ALTERNATIVES FOR GESTATING SOWS

For the pregnant sow, a wide variety of alternative systems to the gestation stall exists (Edwards, 1998) and, since the banning or phasing out of confinement systems in many European countries, these have been in use on both small and large commercial scales. In the UK, group housing systems have been operating since well before this became a legal requirement, and a vast deal of practical experience has accumulated. In synthesising advice and information on such systems, a UK advisory body recognised six different generic categories of gestation housing system (Pig Welfare Advisory Group (PWAG), 1997a,b,c,d,e,f.). These can be summarised as follows:

Outdoor Sows

Low capital cost is incurred in a system where dry sows can be stocked at up to 25 animals per ha in large group sizes, contained by double or single strand electric fencing, housed in simple corrugated iron huts, and fed on the ground (PWAG, 1997a). The system is perceived by consumers to be welfare friendly, and is a requirement of some niche marketing schemes. However, unsuitable soil types, extreme climatic conditions and risks of nitrate leaching and pollution limit the widespread applicability of the system.

Yards or Kennels with Floor Feeding

This is the simplest and cheapest of the indoor systems and can be adopted in almost any building. It may be used with small groups and distribution of feed by hand, or large groups with mechanised feed distribution by 'dump' or 'spin' feeders (PWAG, 1997b).

Yards and Individual Feeders

This is generally the most expensive housing system because of the cost and space requirement associated with having a feeding stall for each sow (PWAG, 1997c). However, it provides good welfare safeguards for the sows by allowing precise individual rationing and protected simultaneous feeding.

Cubicles and Free-Access Stalls

This is a cheaper variant in which less space per sow is required, since the stalls serve as both lying and feeding place (PWAG, 1997d). As with individual feeding stall systems, individual

rationing can only be achieved by hand feeding unless an additional expensive electronic identification system is added, since it cannot be predicted in advance which sow will enter each of the stalls on a given day.

Yards or Kennels with Short Stall Feeders

Further attempts to reduce cost and space per sow have led to development of systems in which only head or shoulder length partitions between feeding places are used (PWAG, 1997e). Because of the associated potential problems with bullying and stealing of feed, these are frequently combined with more specialised feeding systems to reduce this risk. Common examples are the 'Biofix' or 'trickle feed' system, in which feed is metered slowly to each place to prevent inequality of eating speed, and liquid feeding systems in which the greater volume of dilute diet and reduced variability in feeding rate help to minimise problems of aggression.

Electronic Sow Feeders

Large scale automation of dry sow rationing has been made possible by more recent technology which permits individual sows to be electronically identified and allocated a specified amount of diet in a computer controlled feeding station. Economic considerations of utilisation of such an expensive station dictate that this system be used with sequential feeding of individual sows housed in large groups, so that 40-60 sows will typically share each feeding station (PWAG, 1997f).

THE CHALLENGES OF THE ALTERNATIVE GESTATION HOUSING SYSTEMS

The challenges posed by alternatives to confinement systems can relate both to welfare challenges for the animals, and practical and economic challenges for the producer.

Welfare Challenges

The welfare challenges for the group-housed gestating sow relate to social aggression and ability to access a fair share of feed resources. Because of the restricted feed level and chronic hunger experienced by the animals, even on nutritionally adequate diets, competition for feed can be a major source of aggression unless feeding animals are fully segregated. With floor feeding systems, aggression at feeding time can be severe (Brouns and Edwards, 1994; Whittaker et al., 1999) and large variation in body condition can result (Edwards, 1992). In systems with partial feeding stalls (for example, cubicles and free access stalls) significant aggression during feeding can also occur if some sows within the group finish their feed allocations whilst others have food remaining. For this reason, grouping strategies with careful matching of age and body condition are important. Electronic sow feeders require animals to feed sequentially. With good feeding protection and a regular routine, such systems can operate with little aggression. However, any unreliability of the technology due to poor design or maintenance can cause aggression and vice to quickly escalate (Edwards and Riley, 1986). The other source of aggression in group housing systems comes from social instability,

since unfamiliar sows will fight to establish relative social rank. The need to operate batch farrowing systems for health control, while maximising sow pen utilisation, means that sows must be mixed at least once in each cycle. However, in systems where very large group sizes are adopted, either to fully utilise electronic sow feeding equipment or to minimise capital cost of buildings, repeated regrouping may be necessary in smaller herds. Such “dynamic grouping” systems carry inherently greater risk of welfare problems arising from social aggression and a high standard of management and stockmanship is necessary if they are to work effectively.

To minimise the problems with social aggression, a number of general recommendations for system design and management, based on scientific understanding of social behaviour, can be made (Edwards, 1992, 2000). Allowing adequate space for social signalling of submissive behaviour, with a minimum of 2.4 m² per sow in stable groups (Weng et al., 1998), and providing increased floor area and visual barriers within the pen at the time of mixing (Edwards et al., 1993) can reduce the level and severity of injurious behaviours. Where space is limited to save cost, such as in cubicle and free access stall systems, serious problems of aggression during regrouping of sows can occur and this procedure is best done in other purpose-designed mixing pens prior to introduction. The other key factor affecting aggression, even in the absence of competition for feed, is the level of chronic hunger and frustration of feeding motivation. Different approaches to minimising this risk factor can be adopted (Edwards, 1992). Provision of a foraging substrate such as straw bedding, or even smaller recreational amounts of long or chopped straw, allows appropriate expression of foraging behaviour and has been shown in both experimental studies and practical experience to reduce aggression and lesion scores. In unbedded systems, maintaining animals in better body condition and feeding once, rather than twice, daily to allow greater meal size reduces restlessness and aggression. As an alternative to increasing feed energy allowance, providing increased dietary bulk through fibre incorporation can also induce greater satiety as a result of longer feeding time, greater gastro-intestinal distention and prolonged nutrient delivery and heat generation from hindgut fermentation (Meunier-Salaün et al., 2000).

Economic Challenges

The extent to which acceptable economic performance can be realized in alternative loose housing systems for gestating sows depends on two aspects. The first relates to fixed costs arising from the capital cost of system installation, and the second to the level of reproductive performance which can be achieved in a given system relative to the variable cost requirement. Capital costs of group housing systems for dry sows vary widely depending on the building space requirement and sophistication of feeding system adopted. Total space will be greater than for confinement systems, and initial investment or building conversion cost will therefore be higher unless low cost housing structures can be used, such as deep litter systems in uninsulated buildings or hoop structures. The significant reduction in lower critical temperature of group housed sows in deep litter systems, in comparison to individually housed animals in unbedded systems, can mean that the feed penalty associated with less controlled thermal environments is not always great.

Most producer concerns relate to whether less intensive systems can deliver the same level of reproductive performance as the very controlled conditions of stall housing. Many of the early studies on group housing systems in different countries (for example Denmark and USA) have shown reduced reproductive performance relative to stalls in both conception rate and litter size. However, these studies were often carried out in unbedded accommodation with highly competitive feeding systems and staff unfamiliar with group housing systems. It is certainly the case that social stress on sows at key times in the reproductive cycle will result in suppressed oestrus behaviour, reduced ovulation rate and, most importantly, increased embryo mortality (Arey and Edwards, 1998). Adverse effects of stress have been identified at all levels in the hypothalamo-pituitary-gonadal axis as a result of the influence of changes in a number of hormones and neurotransmitters. Avoiding mixing and social competition around the period of insemination and implantation (7-14 days post insemination) by good housing design and feeding management is therefore key to reproductive success. It is for this reason that most EU countries have retained stalls for the first 4 weeks of pregnancy, although large scale surveys in countries with a tradition of group housing (Arey and Edwards, 1998) and more recent studies in countries in the process of adopting such systems (EFSA, 2007) show that well managed group systems can deliver the same high level of reproductive performance.

Comparisons of performance between different dry sow housing systems using industry survey data have periodically been published, especially at times of transition when different systems are running contemporaneously. In the case of the UK, this occurred during the 1980s and 90s. Such survey comparisons generally, but not always, show lower piglet output in outdoor systems, but show few consistent differences between different indoor systems (Edwards, 2000). Feed use is typically 10-15% higher in outdoor systems, and often reported to be 5-10% higher in floor feeding indoor systems. The extent to which this reflects feed wastage, increased sow activity and/or association with poorer quality buildings is uncertain. In survey comparisons of this nature, statistical information is seldom given and the real significance of apparent differences is often unclear. In general, variation within systems is seen to be much greater than differences between them. Experimental within-farm comparisons of different group housing systems have been carried out within the UK (e.g. Stewart et al., 1993; Broom et al., 1995) and elsewhere within Europe (e.g. Bengtsson et al., 1983; den Hartog et al., 1993). Few consistent performance differences between systems have emerged from such studies but welfare has generally been held to be compromised in group feeding systems, and more at risk in electronic sow feeding systems. Studies have generally focussed on different feeding systems, with confounding of other system components such as group size and/or bedding provision. A further concern has been the reporting of increased culling of sows from group housing systems for lameness and leg injuries incurred during aggression at mixing and mounting behaviour during oestrus, particularly in slatted systems. Once again, correct design of housing and management is the key, with adequate space, non-slippery floors and correct slat and void dimensions.

The recent EU scientific review (EFSA, 2007) therefore concluded that reproductive performance of sows in group housing, even over the breeding period, can be kept at the same level as individually confined sows, and that welfare improvements associated with less restrictive housing need not impair production efficiency.

THE NON-CONFINEMENT ALTERNATIVES FOR FARROWING AND LACTATING SOWS

As with gestation systems, a variety of different approaches to design of non-confinement systems for the farrowing and lactating sow have been tried (Edwards and Fraser, 1997; Weber, 2000). However, relatively few of these have been subject to large scale commercial evaluation. The alternatives can be categorized into three general types:

Individual Housing with Reduced Sow Confinement

Many of these systems have tried to retain the commercially desirable characteristics of the farrowing crate, by making alterations to geometry without substantial increases in space requirements. The 'turn round' crate (McGlone and Blecha, 1987) is a modified design with the side rails flared outward at the back of the crate to allow sows to turn around. The Ottawa crate (Fraser et al., 1988) uses inward-sloping bars to limit the area where the sow can lie and to control the lying movements of the sow, whilst still allowing her space to turn around. An ellipsoid crate design also allows the sow to turn around (Lou and Hurnik, 1994). An alternative approach, which eliminates the crate entirely, is the sloped floor or "hillside" pen (Collins et al., 1987). These pens are comparable in size to a crated pen (1.8 x 1.8 or 2.3m) with a slope of 10-17% on a fully slatted floor and a heated creep area at the base of the slope. In all of these designs, where the sow can turn around but has limited floor space, hygiene considerations dictate the use of fully slatted floors. To accommodate bedding or nest-building material, larger pens are needed to provide separate lying and excretory areas for the sow. Such designs include the "Schmid box" (Schmid, 1993), a 2.5 x 3m pen in which a bedded nest area is separated from an activity area (with feeding and drinking facilities) by a division which contains a heated creep box, the Weribee Farrowing Pen (Cronin et al., 2000) and Swiss designs developed at FAT, Tanikon (Weber, 2000).

Group Farrowing Systems

The much greater space allowance necessary for increased locomotion in the nest site location phase of pre-farrowing behaviour can only be economically encompassed within group housing designs, which also offer possibility of social contact between lactating sows. The most widely used commercial example is the traditional outdoor production system, where a group of sows has unrestricted use of a large paddock with individual farrowing huts. There have been many attempts to replicate this approach indoors under conditions of more restricted space, with a variety of different nest site designs ranging from very simple wooden nests (Fisher, 1990; Algers, 1991), through small square pens with a triangular creep area in one corner (van Putten and van de Burgwal, 1990; Boe, 1993; Goetz and Troxler, 1993; Rudd et al., 1993; Arey, 1994), and walk through crate designs (Rudd et al., 1993; Arey, 1994), to highly sophisticated nest designs such as the Freedom Farrowing system (Baxter, 1991).

Two Stage Systems

A compromise position involves retaining the crate for parturition and early lactation, and then allowing more freedom once the piglets have become established. This can be achieved

by systems in which the sow is initially crated, and subsequently given access to a larger pen (for example swing-side crates, Gustafsson, 1982), or by moving the sow and litter from a specialized farrowing facility to a cheaper, “multisuckling” group facility for the rest of lactation (Wattanukul et al., 1997).

THE CHALLENGES OF THE ALTERNATIVE FARROWING AND LACTATION HOUSING SYSTEMS

Once again, the challenges posed by alternatives to confinement systems can relate both to welfare challenges for the animals, and practical and economic challenges for the producer. However, in this instance they have a common factor in the issue of piglet mortality.

Welfare Challenges

Although designed to give welfare improvements in comparison with the farrowing crate, many of the systems still pose some degree of welfare challenge for the sow. In individual pen designs with minimal space, hygiene considerations dictate the use of fully slatted floors and preclude the use of bedding material to provide a nesting substrate. True expression of nest-building motivation is therefore not possible. Whilst research indicates that lack of space is a greater stressor than lack of nesting substrate in the pre-parturient period (Jarvis et al., 2002), this situation is still far from ideal. Even the larger individual pens systems fail to allow enough space for the sow to express the increased locomotion seen in the phase of nest site location. Nor do they allow her to escape the attentions of the litter and reintegrate with the social group as lactation progresses. Group housing systems, which do allow such behaviours, can also have some sow welfare problems. Sows in semi-natural conditions isolate themselves before farrowing and, when penned together, show increased aggression towards other sows as parturition approaches (Arey et al., 1992). If space is restricted, serious bullying can occur.

Economic Challenges

For most alternative lactation systems, capital cost will be increased because of greater space requirement. The exceptions can be the simple group systems outdoors in paddocks or in bedded yards, where costs for building structures can be low in areas where conditions are suitable for such housing. However, the much greater economic issue, and at the same time welfare issue, is the ability of alternative systems to give the same level of pre-weaning piglet survival as the farrowing crate. The performance of the alternative systems in this respect has been reviewed several times in recent years (Edwards and Fraser, 1997; Wechsler and Weber, 2007, EFSA, 2007).

The majority of comparisons of farrowing crate and open pen systems, both in specific experiments and larger scale farm surveys, have shown improved piglet survival where crates were used. Where this was not the case, overall levels of survival were frequently much poorer than currently accepted norms. Whilst data are not always presented, it is important to consider total survival, since misdiagnosis of causes of mortality is common under commercial conditions (Edwards, 2002) and, in many studies, a higher incidence of crushing

in non-crate systems is partially offset by a lower incidence of stillborn piglets. Results from other modified crate and individual pen systems have been variable. In many cases, only experimental studies with small sample sizes have been reported. Whilst these have sometimes given promising results, larger scale evaluations carried out subsequently have often failed to sustain high survival levels; for example with the turn round crate and sloped floor crate (Grissom et al., 1990) or Schmid box (Damm et al., 2005). The robustness of systems under commercial conditions, where staff may have less understanding of the requirements to make them work effectively, is an important consideration.

Farrowing systems where sows are kept in groups have often given the worst survival results as a result of failure of a proportion of animals to farrow in the designated nests, disturbance of sows by others during the perinatal period and cases of premature desertion of the litter. Whilst these risks could sometimes be managed under experimental conditions, they proved to be too demanding under commercial conditions. The exception to this has been outdoor farrowing systems, where large scale operations under good management routinely achieve comparable survival levels to those seen in farrowing crate systems, particularly when individual farrowing paddocks are used. The possibility of isolation and minimal disturbance, combined with use of genotypes expressing both better piglet vitality and maternal behaviour, seems to underlie this success. Indoor “multisuckling” systems, which were widespread in the past, but lost favour because of variable performance and difficulty of management, can be economically attractive because of the lower capital cost of such accommodation, but careful management is still necessary if piglet welfare is not to be compromised. Newly grouped litters may experience major disruption of suckling, with an increased frequency of unsuccessful suckling, a high degree of cross-suckling and an increased number of piglets at the udder of individual sows during any suckling attempt (Wattanakul et al., 1997). Hence, piglet growth rate may decrease dramatically during the first few days after grouping, and mortality can be increased.

After many disappointing attempts, however, it does finally appear that non-crate systems might have the potential to deliver acceptable levels of survival under commercial conditions. More recent large scale studies in Switzerland (Weber et al., 2007), Australia (Cronin et al., 2000) and Denmark (EFSA, 2007) have given comparable total survival in crate and pen systems, with greater crushings in pen systems being offset by higher losses from other causes in crate systems. The importance of adequate size of the pens, at least 5 m², for the sow to perform appropriate pre-lying behaviours has been highlighted as a critical design feature in achieving this. However, the absolute levels of mortality in these studies still tend to be at the higher end of current commercial norms, and further development and evaluation studies are still required before widespread commercial adoption could be recommended. It is worthy of note however, that Sweden has been operating loose farrowing systems commercially for some years without disastrous consequences.

In summary, whilst non-crate systems for farrowing and lactation now show promise, larger scale commercial comparisons are still required in order to adequately weigh the benefits to sow welfare against possible disadvantages in terms of piglet welfare, cost or practical management.

THE WAY FORWARD

For both gestating and lactating sows, non-confinement systems which can improve sow welfare without unacceptably compromising piglet welfare or production economy do exist. Making these systems an effective commercial reality involves more than just implementing a building design. Although the system is often considered to be the situation into which the sow is placed, factors associated with the sow herself can interact with other components to play a crucial role in system success. Certain genotypes of sow are better adapted to extensive systems, requiring a robust individual, than others. This is particularly apparent in outdoor systems but can also be relevant in indoor group-housing systems. Selection of genotypes for traits more relevant to social and maternal success in non-confinement systems (Baxter et al., 2007; Roehe et al., 2008) will be a critical part of a successful strategy. It is also becoming apparent that the previous physical environment and social experience of the animals can influence later group behaviour (van Putten and Buré, 1997), and understanding and utilising these developmental influences will also be important. Finally, it must be recognised that the system cannot be divorced from the human input of management and stockmanship. Sow observation and management during key production stages such as breeding and farrowing become more critical as artificial aids are reduced.

CONCLUSIONS

Pig producers must consider the long term future of their industry, which ultimately depends on the acceptance of pig production methods by consumers and the wider society. The close confinement of sows in barren environmental conditions gives rise to major public concern for their welfare. Many alternative loose housing systems for dry sows exist, and have been in widespread use for a number of years. They have the potential to deliver both higher welfare and good reproductive performance, but careful attention to feeding and management to prevent social stress is critical to success. Adoption of alternative non-confinement systems for farrowing and lactation is more problematic. Despite their routine use in some EU countries at the current time, systems which guarantee good piglet survival under large-scale indoor production conditions have yet to be commercially proven. However, promising developments are now emerging which, together with appropriate changes in genetics and management offer hope for the future. The extent to which alternatives succeed is likely to depend on the scale of operation, the skill of stockpeople and the philosophy and motivation of the producer. However, such considerations cannot be divorced from production economics. Producers in a very competitive industry can only operate within the bounds of profitability. Initiatives that reduce net margin are not sustainable and any systems which significantly reduce output or increase capital or running costs are only viable if associated with a protected market or reliable product premium.

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NEW OPPORTUNITIES FOR REPRODUCTIVE MANAGEMENT

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ABSTRACT

The majority of reproductive management strategies are directed at providing the best production environment for adult animals. Obviously, this is necessary and appropriate. However, there is an increasing amount of evidence that supports the concept that there are key developmental periods during the maturation of young animals that are critical to their reproductive success as adults. In swine, one of these critical periods is the first 3 weeks after /birth which coincides with lactation on most swine farms. Several studies were conducted to examine the impact of reducing the litter in which future replacement gilts and boars were raised on their reproductive function as adults. The rationale for this strategy was that gilts and boars raised in small litters would have less competition, improved access to nutrition, and, thus, enhanced development during this critical period compared with their counterpart raised in a large litter. This, in turn, should result in better reproductive function as an adult. The study with sows is still in progress. However, through 3 parities, sows raised in litters of 7 piglets or less were less likely to be culled and had higher farrowing rates and larger litters than sows raised in litters of 10 or more piglets. The cumulative effect of these advantages was estimated to be an additional 1.1 piglets weaned per gilt that entered production. A separate study with replacement A.I. boars has just been completed. Boars raised in litters of 6 piglets or less reached puberty sooner, produced more spermatozoa per ejaculate, and appeared to be more fertile compared with boars raised in litters of 9 piglets or more. Assuming that a boar remains in a boar stud for at least 73 weeks and insemination doses consist of 3 billion spermatozoa, boars raised in small litters produced in excess of 380 more doses than boars raised in large litters over their productive life. Thus, it appears that enhancing the neonatal environment of replacement gilts and boars is a new opportunity for enhancing reproductive management.

INTRODUCTION

In 2007, sow replacement rates varied from 30 to 89% with an average of 68% for herds using the PigChamp® recording system in the U.S. and Canada (PigChamp, Inc., 2007). Several large retrospective studies have reported that females are most likely to leave the herd during entry-to-first service and weaning-to-service after their first lactation. Thus, the decision to remove a sow from the herd is largely based upon her failure to reproduce in a timely fashion, which is often referred to as “involuntary culling”. The situation with boars is somewhat different. Most boars in North America are replaced 12 to 18 months after they enter production (Knox et al., 2007). This relatively short usage period is related to the need to

maximize genetic improvement and typically is independent of a boar's performance. In other words, even outstanding boars would be culled to make room for the next generation. This type of culling is referred to as "voluntary culling".

Both types of culling limit the reproductive efficiency of swine herds. For sows, involuntary culling creates a situation in which the majority of females are being replaced before they reach their peak biological period of productivity which typically occurs between parities 3 and 6. For boars, voluntary culling occurs during a period of time when their semen production and fertility is still increasing and also before it has reached optimum levels. From a management perspective, most producers are faced with two different situations – one in which the longevity or productive life of sows needs to be increased and another in which the output of boars needs to be increased during a relatively short period of time.

Most attempts to address these productivity issues have focused on the management of adult sows and boars and often produce equivocal results on commercial operations (Flowers, 1997; 1998). The observed variation in results with most of these intervention strategies suggests that they may be simply correcting problems inherent and unique to a given production environment. Obviously, this is very important, but typically does not elicit the same response on every operation.

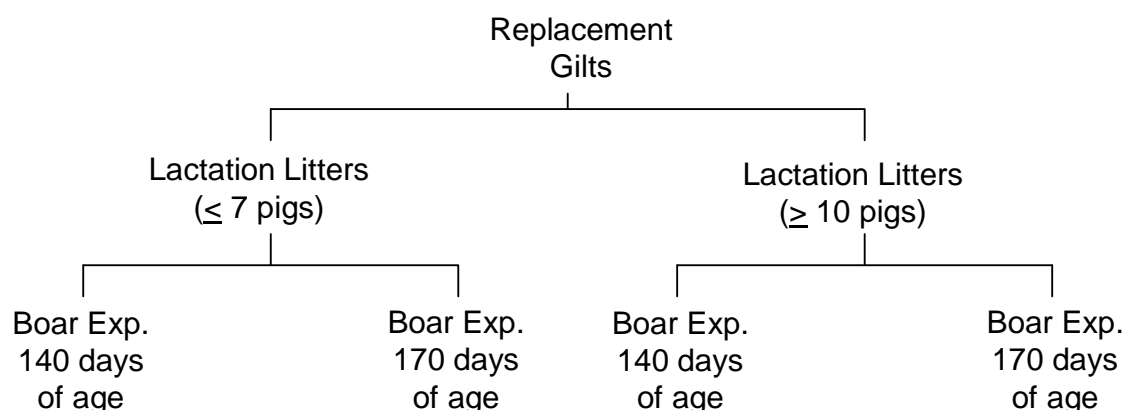
From a physiological perspective, important developmental events occur in both gilts and boars shortly after birth. These events establish the reproductive tools that animal's have to work with as adults. In females, the number of egg nests and the formation of follicles in the ovary (Morbeck et al., 1993) and the size of the uterine endometrium (Bartol et al., 1993) increase during the first few weeks after birth. These are important observations because it means that there is a period of time shortly after birth during which management conditions have the potential to affect the number of eggs that sows can ovulate each time they are in estrus and the number of fetuses that their uteri can maintain each time they become pregnant as adults. Similarly, the cells in the testicles and secondary sex glands that are responsible for the production of sperm and seminal fluids undergo two periods of rapid development (McCoard et al., 2003) The first occurs during the first 3 weeks after birth and is thought to be the most critical for adult reproductive function. Consequently, the manner in which both potential replacement boars and gilts are managed early in life may present new opportunities for reproductive management. The primary objective of this paper is to present some relatively new information with regards to how management early in the lives of gilts and boars can influence their reproductive performance as adults.

MANIPULATION OF THE NEONATAL ENVIRONMENT AND SOW LONGEVITY

Currently, we are in the process of collecting data with regard to how manipulation of the neonatal environment of replacement gilts affects their lifetime productivity or longevity. In essence, we are attempting to determine if there are strategies that can be introduced early in the management of replacement gilts that will increase the proportion of sows that produce at least 3 parities. The study is being conducted within an 80,000-sow commercial production pyramid that uses "in-house" gilt multiplication. In this system, replacement gilts remained

"on-site" until they were about 190 days of age; and then were sent to commercial farms. At birth, gilts were randomly allocated to a factorial arrangement of treatments involving neonatal litter size (≤ 7 litter mates or ≥ 10 litter mates); and puberty stimulation (boar exposure @ 140 days of age or boar exposure @ 170 days of age). The overall design of the experiment is shown in Figure 1. Between 190 and 210 days of age, gilts were sent to commercial farms. The commercial farms were P.R.R.S. positive, but considered to be P.R.R.S. stable. At the present time, all sows still in the herd have just weaned their third litter.

Figure 1. Outline of the experimental design for sow longevity study.



Results from the study are shown in Tables 1 through 4. The primary measure we used for sow longevity was the proportion of sows still in the herd after 3 parities (Table 1). Both being reared in a small litter and boar exposure at 140 days of age had a positive effect on sow longevity. The relative advantages were about 16% and 10% for being raised in a small litter and receiving boar exposure at 140 days of age, respectively. These effects were additive, so approximately 26% more sows raised in small litters and exposed to boars at 140 days of age were still in production after weaning three litters compared with their counterparts raised in large litters and exposed to boars at 170 days of age.

The primary measures used to evaluate reproductive performance in the study were farrowing rate (Table 2) and number of pigs born alive (Tables 3 and 4). Both being raised in a small litter and receiving boar exposure at 140 days of age had a tendency to increase farrowing rate over three parities. These effects were additive. Early puberty stimulation increased farrowing rate by 6.0%, whereas being raised in a small lactation litter resulted in a 4.0% improvement. As a result, sows that were raised in litters of less than 7 pigs and were given boar exposure at 140 days of age had a 10.0% higher farrowing rate compared with those that were not.

Table 1. Effect of neonatal litter size and puberty induction strategies on proportion of sows remaining in herd after three parities.

Puberty Stimulation	Neonatal Environment		<i>Main Effect of Puberty Stimulation</i>
	Small Litters (≤ 7 pigs)	Large Litters (≥ 10 pigs)	
Boar Exposure @ 140 days	60.0% (180 / 300)	42.2% (133 / 315)	50.9% ^a (313 / 615)
Boar Exposure @ 170 days	46.0% (138 / 300)	32.6% (98 / 300)	39.3% ^b (236 / 600)
<i>Main Effect of Neonatal Environment</i>	56.3%* (338 / 600)	37.6% (231 / 615)	-----

*significantly different from Gilts raised in Large Litters ($p < 0.05$)

^{a,b} means with different superscripts within the same column differ ($p < 0.05$)

Table 2. Effect of neonatal litter size and puberty induction strategies on farrowing rate over three parities.

Puberty Stimulation	Neonatal Environment		<i>Main Effect of Puberty Stimulation</i>
	Small Litters (≤ 7 pigs)	Large Litters (≥ 10 pigs)	
Boar Exposure @ 140 days	88.7% (642 / 724)	83.9% (533 / 635)	86.5% ^a (1175 / 1359)
Boar Exposure @ 170 days	81.8% (539 / 659)	78.9% (446 / 565)	80.5% ^b (985 / 1224)
<i>Main Effect of Neonatal Environment</i>	85.4%* (1181 / 1383)	81.5% (979 / 1200)	-----

*significantly different from Gilts raised in Large Litters ($p < .10$)

^{a,b} means with different superscripts within the same column differ ($p < 0.10$)

Table 3. Effect of neonatal litter size and puberty induction strategies on average number of pigs born alive through three parities (numbers in parenthesis are number of observations).

Puberty Stimulation	Neonatal Environment ¹		<i>Main Effect of Puberty Stimulation</i>
	Small Litters (≤ 7 pigs)	Large Litters (≥ 10 pigs)	
Boar Exposure @ 140 days	$10.8 \pm 0.2^*$ (642)	10.2 ± 0.2 (533)	10.5 ± 0.2 (1175)
Boar Exposure @ 170 days	10.4 ± 0.2 (539)	10.0 ± 0.1 (446)	10.2 ± 0.2 (985)
<i>Main Effect of Neonatal Environment</i>	$10.6 \pm 0.2^*$ (1181)	10.1 ± 0.1 (979)	-----

¹Neonatal Environment x Puberty Stimulation interaction ($p < 0.05$)

*significantly different from Gilts raised in Large Litters ($p < 0.05$)

Table 4. Effect of neonatal environment and puberty induction strategies on numbers of pigs born alive in parities 1, 2 and 3 (numbers in parentheses are numbers of observations).

Production Status	Boar Exposure @ 140 days of age		Boar Exposure @ 170 days of age	
	Small Litter	Large Litter	Small Litter	Large Litter
Parity 1	10.2 ± 0.2 (249)	9.8 ± 0.2 (233)	10.0 ± 0.2 (235)	9.6 ± 0.2 (209)
Parity 2	10.8 ± 0.2 (213)	10.4 ± 0.2 (167)	10.4 ± 0.2 (166)	10.1 ± 0.2 (139)
Parity 3	11.5 ± 0.2 (180)	11.0 ± 0.2 (133)	11.0 ± 0.3 (138)	10.6 ± 0.2 (98)

There was an interaction between neonatal environment and puberty stimulation for numbers of pigs born alive. When puberty stimulation occurred at 140 days of age, sows raised in small litters had increased numbers of pigs born alive compared with sows raised in large litters. In contrast, when puberty stimulation occurred at 170 days of age, there was only a tendency for sows raised in small litters to have increased numbers of piglets. Because the interaction was one of magnitude, the overall main effect of neonatal environment was significant with sows being raised in small litters having about 0.5 pigs more per litter than

those raised in large litters. There was no effect on puberty stimulation on numbers of pigs born alive.

Changes in numbers of pigs born alive for parities 1 through 3 are shown in Table 4. What is interesting to note from these data is that even though sows raised in small litters had an additional 0.5 pigs per litter over 3 parities, differences among various treatment combinations by the end of the third parity were quite large. For example, there was almost a pig per litter difference (0.9) for sows raised in small litters and given boar exposure at 140 days (11.5) compared with sows raised in large litters and given boar exposure at 170 days (10.6).

The results from this study illustrate clearly that the neonatal environment and the age at which puberty stimulation occurs has a significant influence on adult reproductive performance. Based on the differences observed in longevity, farrowing rates, and numbers of pigs born alive, estimates as to what production systems might expect to achieve with different management strategies was estimated. This was done by determining the number of litters each female farrowed and multiplying it by the average number of pigs born alive over three parities (Table 3) within each treatment. These estimates are shown in Table 5. Boar exposure at 170 days of age for gilts raised in a neonatal litter probably represents the most common gilt development strategies currently in the U.S. swine industry. Consequently, it seems logical to consider this as the treatment that best reflects what most production systems are currently doing. Based on the estimations presented in Table 5, simply limiting the lactational litter size of future replacement gilts to 7 piglets or less would increase the lifetime productivity of each sow that enters production by 3.3 pigs through 3 parities, or roughly by 1.1 pigs per litter. A similar improvement of 3 pigs would be expected by providing boar exposure at 140 days of age. If both were employed effectively, then one would expect an improvement of 6 pigs per female over 3 parities, or about 2 pigs per litter.

Table 5. Estimated effects of different gilt development strategies on total number of pigs produced per bred gilt over three parities.

Strategy	Number of Litters Farrowed / Gilt	Average Number Born Alive / Litter	Total Pigs / Bred Gilt
Boar exposure @ 170 days of age + Large neonatal litter size	1.60	10.0	16.0
Boar exposure at 140 days of age + Large neonatal litter size	1.86	10.2	19.0
Boar exposure @ 170 days of age + Small neonatal litter size	1.86	10.4	19.3
Boar exposure at 140 days of age + Small neonatal litter size	2.23	10.8	24.1

An important point to consider is whether these experimental treatments could be easily adapted into current commercial production systems. Given the management structure of many operations in the swine industry, providing good, consistent boar exposure to gilts at 140 days of age probably would be technically very challenging and present problems with maintaining strict biosecurity. Thus, it may not be practical for many operations. In contrast, because males born as litter mates to replacement gilts have limited economic value as market animals, strategic cross-fostering programs for sows nursing potential replacement gilts is a technique that should be easy to implement and improve sow longevity and productivity.

MANIPULATION OF THE NEONATAL ENVIRONMENT FOR A.I. BOARS

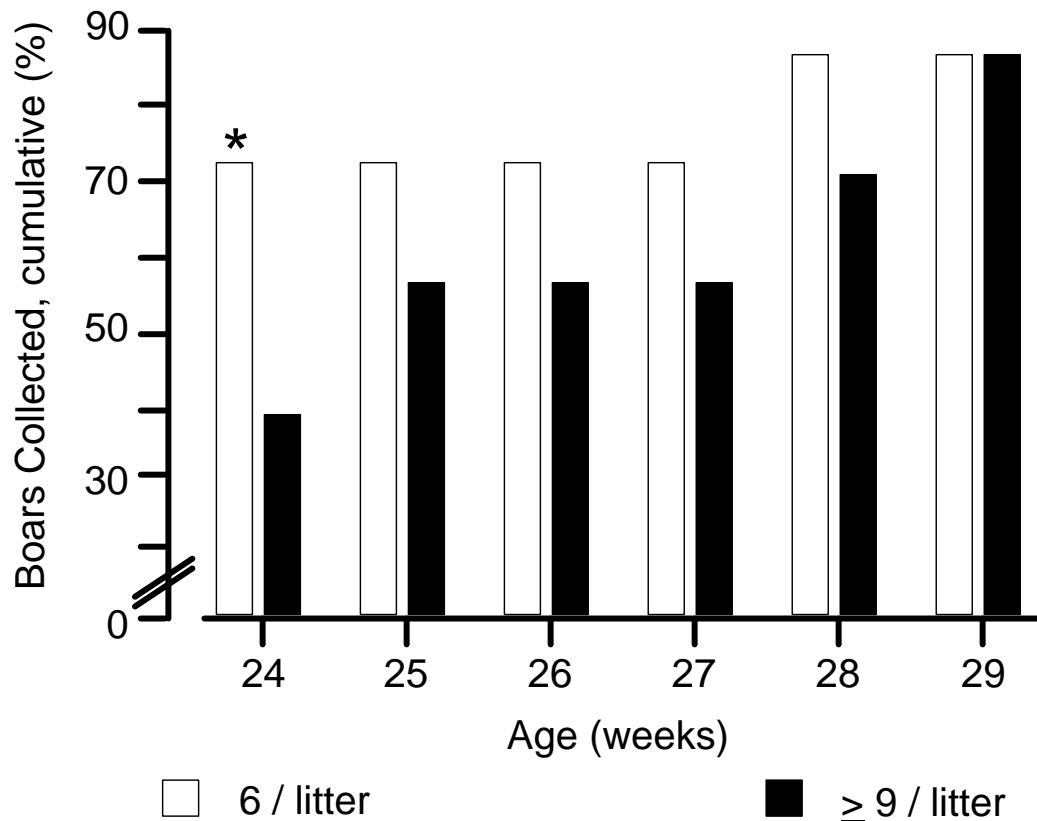
In order to examine the influence of the neonatal environment on adult reproductive performance, 40 terminal-line, crossbred boars were crossfostered at one day of age in such a way that littermates were raised in litters of 6 ($n=20$) or in litters of 9 or more pigs ($n = 20$). Boars were selected from birth litters that had equal numbers of gilts and boars and crossfostering was done in such a way that potential milk production difference among sows were minimized. For example, if sow A gave birth to 5 boars and 5 gilts and she was randomly selected to nurse a litter of 9 or more piglets, then 4 of her sons were fostered off to four different sows and she received 4 new boars from other sows, thus, creating a situation in which she nursed 5 different genotypes of boars. The study was conducted with a group of boars born in October and another group born in April creating a Fall and Spring replicate ($n = 10$ boars / treatment / season). The same sires were used to produce the experimental animals in each replicate.

Litters were weaned at 18 days of age and boars were managed according to normal industry practices through the nursery and finishing phases of production. The only exception was that boars were given 4 and 10 square feet of floor space per pig during the nursery and finishing phases, respectively. An important component of the experimental design was that boars from the small (6 pigs) and large litters (≥ 9 pigs) were co-mingled at weaning. This created a situation in which animals from both treatments were in same pens from weaning through finishing. At 5 months of age, boars were moved from pens and housed in individual crates. At 5.5 months of age boars were trained for collection with a dummy sow and collected once per week until they were at least two years of age.

Training for semen collection began when boars were 24 weeks of age (~ 155 days of age). There were no differences in the number of boars successfully being collected by the end of the training period (Figure 2). However, the overall training period was significantly reduced for boars from small (10 days) than large litters (30 days). These data indicate that boars allowed to nurse in litters of 6 pigs or less had greater libido than boars nursing in litters of 9 or more pigs. Boars raised in small litters also had increased testicular size at relatively young ages compared with boars raised in large litters (data not shown). One interpretation of these data is that testicular maturation and thus testosterone production began earlier. This, in turn, should result in attainment of puberty at a younger age as measured by their desire to mount a dummy sow and be collected. It is particularly impressive that all 20 boars that nursed in small litters mounted and were collected during the first 5 days of the training period. In

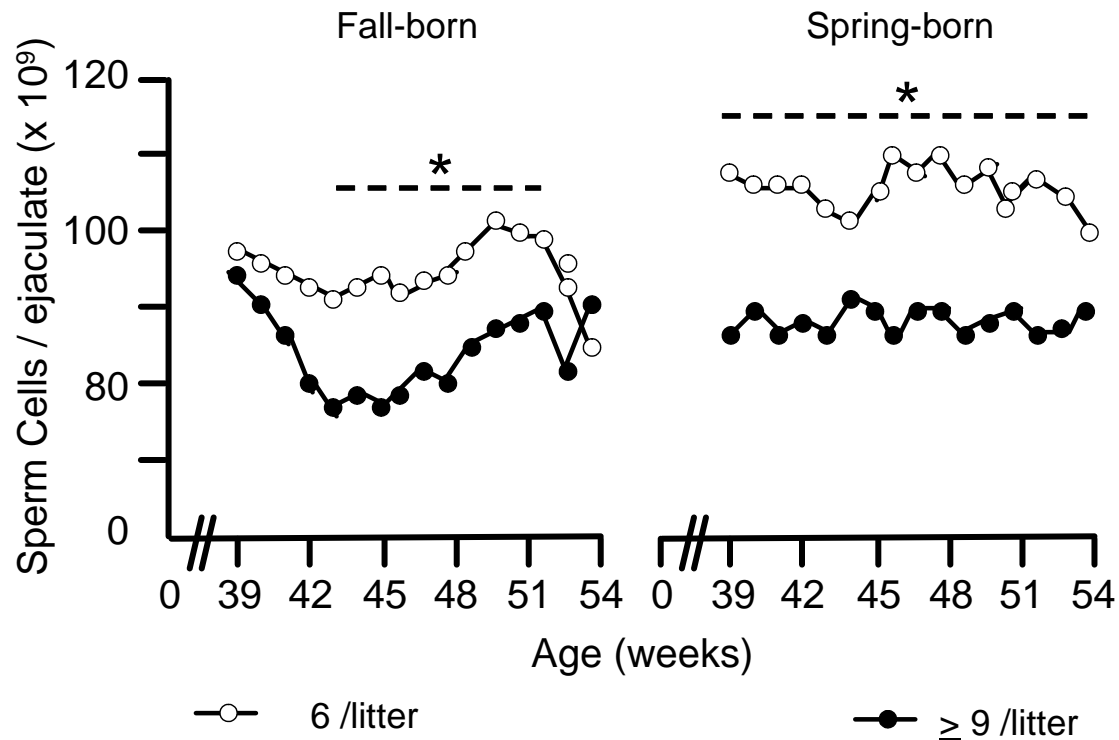
contrast, only 5 of the 20 boars that nursed in large litters were trained for semen collection during the first 5 days of the training period.

Figure 2. Effect of neonatal litter size on boars trained for semen collection on a dummy sow. *More boars raised in litters of 6 were trained to collect from a dummy sow compared with boars raised in litters of ≥ 9 ($P < 0.05$).



Numbers of spermatozoa per ejaculate are also greater in boars raised in small versus large litters. It is important to remember that there is a 6 month difference in age between the fall-born and spring-born replicates, so these data have been analyzed and presented separately (Figure 3). In the spring-born replicate, boars raised in small litters produced about 10 billion more spermatozoa per ejaculate about 75% of the time (61 weeks) between 42 and 112 weeks of age. In contrast, for those born in the fall, boars raised in small litters consistently had 20 billion more spermatozoa per ejaculate than their counterpart raised in large litters beginning at 39 weeks of age until the end of the study ended when they were 2 years of age. From a practical perspective, the collective advantage of being raised in a small litter was an additional 200 insemination doses (600 billion spermatozoa) for boars born in the Spring and an extra 567 insemination doses (1700 billion spermatozoa) for boars born in the Fall. No significant differences among treatments in motility, morphology, acrosome morphology, acrosin activity, or capacitation status were observed (Table 6).

Figure 3. Effect of neonatal litter size on number of spermatozoa per ejaculate between 39 and 54 weeks of age. * Boars raised in litters of 6 produced ejaculates with more spermatozoa compared with boars raised in litters of ≥ 9 ($P < 0.05$).



Finally, boars raised in small litters sired, on average, around 65% of the piglets resulting from heterospermic inseminations. Consequently, they appear to be more fertile than boars raised in large litters (Table 6). It is difficult to translate this relative advantage into differences in farrowing rate and numbers of pigs born alive at the present time. This is due to the fact that use of heterospermic inseminations and paternity testing of the resulting offspring is a relative assessment of fertility. In other words, it can be used to rank boars from most to least fertile. However, this technique cannot really establish whether the most fertile boar produces farrowing rates of 95% or 85%. Nevertheless, these data do indicate that regardless of what the actual fertility level, boars raised in small litters would be higher than those reared in large litters.

The same question that was posed for the study currently underway involving manipulation of the neonatal environment for gilts is equally valid for boars – is it practical under industry conditions? Given the fact that the productive life of an A.I. boar is so short and this is basically a voluntary decision based on enhancing the rate of genetic improvement, the answer is “yes”. Gilts from litters bred specifically for the production of A.I. boars also have limited usefulness sows and are most likely destined for market. In addition, most terminal line sows tend to have smaller litters compared with most maternal line sows. Thus, producers probably have more flexibility and a greater opportunity for strategic crossfostering in litters of replacement boars compared with those with replacement gilts.

Table 6. Semen quality and fertility estimates from boars raised in small or large litters during lactation (mean \pm s.e.).

Variable	Winter		Summer	
	6 / litter	≥ 9 / litter	6 / litter	≥ 9 / litter
Motile spermatozoa (%)	85.3 \pm 5.7	86.8 \pm 6.5	88.4 \pm 4.3	80.8 \pm 5.7
Normal morphology (%)	91.3 \pm 3.4	84.6 \pm 4.5	88.3 \pm 5.1	82.1 \pm 6.1
Normal acrosome morphology (%)	90.4 \pm 4.7	83.2 \pm 3.6	90.6 \pm 6.1	80.3 \pm 4.2
Acrosin activity (%)	95.3 \pm 4.5	90.3 \pm 3.2	92.8 \pm 4.1	93.4 \pm 4.6
Normal capacitation (%)	80.2 \pm 7.8	70.3 \pm 6.3	85.3 \pm 6.9	79.7 \pm 4.2
Seminal plasma proteins (relative units per ejaculate)	12.2 \pm 2.4	10.1 \pm 2.0	12.9 \pm 2.1	10.7 \pm 1.4
Proportion of piglets sired in heterospermic matings (%)*	67.3 \pm 5.7	32.7 \pm 5.4	63.5 \pm 4.8	36.5 \pm 4.3

* Boars raised in litters of 6 sired more pigs than boars raised in litters of ≥ 9 (P = 0.02)

CONCLUSIONS

Management of future replacement gilts and boars has a significant impact on their reproductive capabilities as adults. Strategies that reduce competition and enhance growth during the first 3 weeks of life positively affect the longevity and prolificacy of sows and the numbers and fertility of spermatozoa produced by boars. Reduction of the number of piglets in which replacement gilts and boars are raised is one such strategy that appears to be effective from both a practical and biological perspective.

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WHAT DOES THE FUTURE HOLD?

IMPACTS ON FURTHER GROWTH OF THE NORTH AMERICAN PORK INDUSTRY

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ABSTRACT

The world in which North American pork producers operate has fundamentally changed. Business models based on low priced oil, grain, and fertilizer face a new world where none of these exist. Higher feed costs will eventually reduce production of animal proteins leading to a new equilibrium with higher pork prices at smaller supplies than would have occurred otherwise. While the new equilibrium is expected to provide a return on investment sufficient to sustain the down-sized sector, the transition will be stressful. Packing capacity that was a significant concern in 1998 appears to have weathered the storm in 2007. Unless there is a herd reduction during 2008 packing capacity will be challenged in the fourth quarter. At the other extreme, a smaller production sector due to higher feed costs will result in mothballing packer capacity in the long run. Besides the obvious and immediate challenge of higher feed costs and low hog prices, there are additional challenges to growth. Finally, constraints on production practices, or at least documentation of practices, are increasingly important and market access is replacing governmental regulations on issues of environment, animal care, and pharmaceuticals. Market access and the documentation needed to assure market access may restrict growth by increasing cost of production.

INTRODUCTION

Until ethanol came along, the pork industry was the most rapidly changing, most exciting sector of agriculture. For a variety of reasons the pork sector has lost its shine and risks being drowned out by the current biofuel binge. Up until six month ago the hog production sector was defying economic gravity. The combined US and Canada hog inventories posted 16 consecutive quarters of slow growth and US producers enjoyed the longest stretch of profits in at least 35 years. It appeared that producers had found that nirvana where increasing supply was just below the growth in demand. Reality arrived in the fall of 2007 when large supplies pressured hog prices lower and feed prices headed higher. Losses in late 2007 and early 2008 were estimated to exceed \$25/head for Iowa farrow-to-finish operations. Regions with higher feed cost or higher freight costs experienced losses sooner and larger.

The extended period of profitability has been credited to disease pressures in 2006. Specifically, circovirus that swept through North American herds in 2006 increased death loss and culls in the finisher and reduced the number of hogs that lived until they died. An effective vaccine was widely adopted by summer of 2007 and a surge of hogs hit the market in the fourth quarter. The percent of hogs reach slaughter in the fourth quarter increased

dramatically between the 2006 and 2007 (Figure 1). Second, third and fourth quarter values in 2006 had lagged the five year average quantifying what everyone suspected, circovirus had significantly reduced supplies. If the higher livability continues at the fourth quarter pace, supplies will remain large.

Besides healthier pigs, where did the current record production come from and what are the prospects for continued growth of the industry. The North American breeding herd has increased modestly since January¹ 2000 and with the exception of 2001 the two countries have moved in opposite directions (Figure 2). Since 2005 Canada has decreased and the US has increased sow numbers.

Figure 1. U.S. barrow and gilt slaughter as percent of U.S. pig crop two quarters earlier adjusted for Canadian imports.

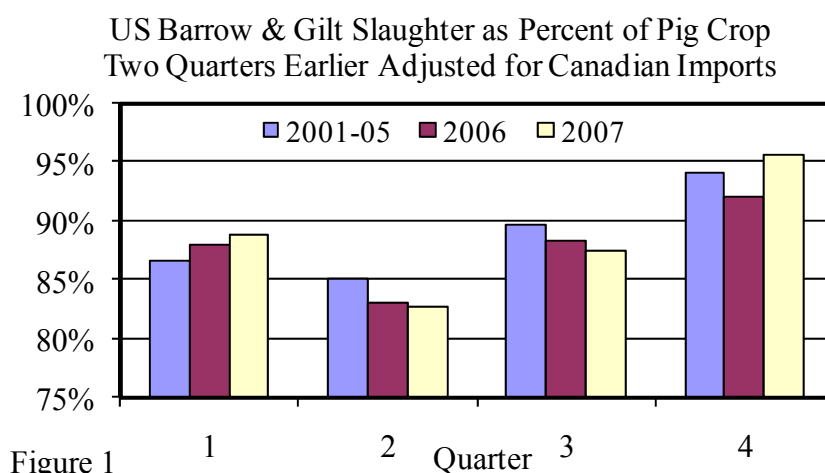
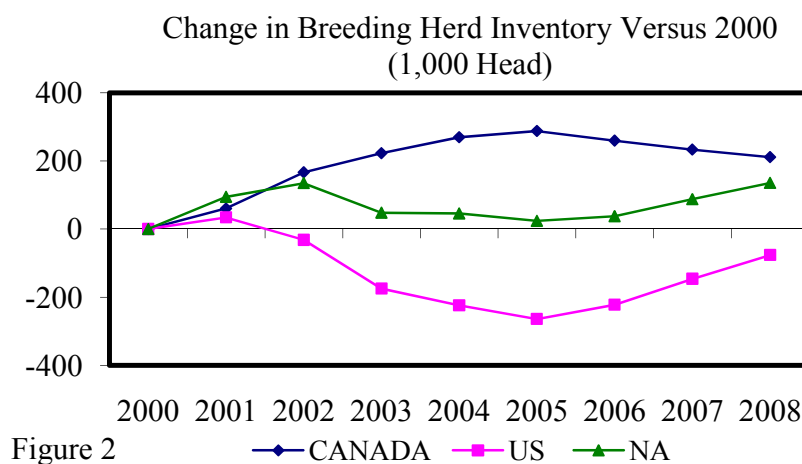


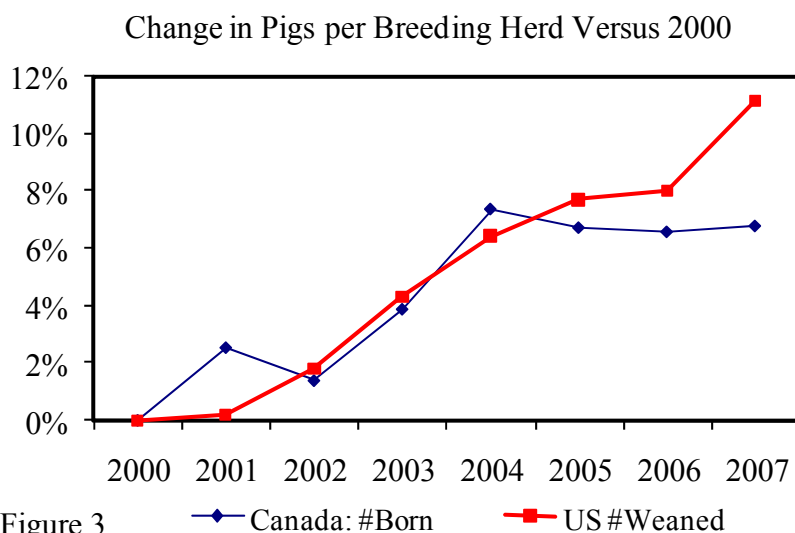
Figure 2. Change in breeding herd inventory versus 2000 (1000 head).



¹ The US Inventory is measured in December, one month earlier

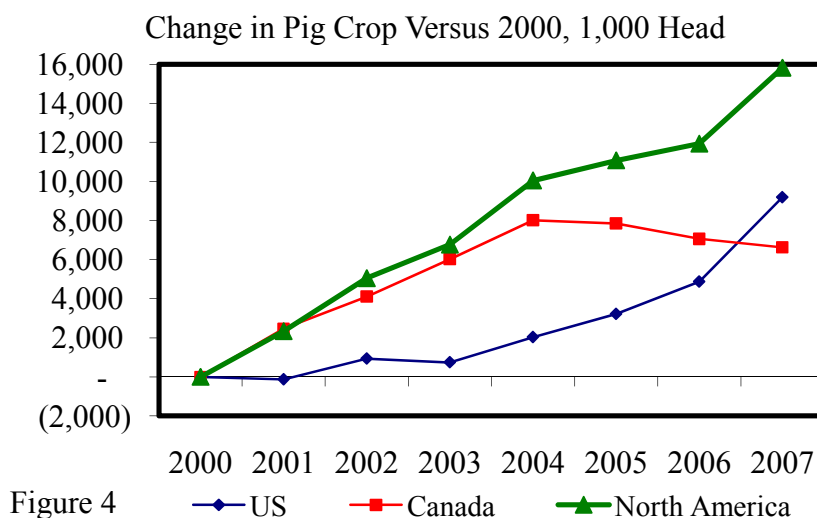
Another source of hog supply is increased productivity. North American producers have made significant progress in breeding herd productivity in recent years (Figure 3). Compared to 2000 the number of pigs per animal in the breeding herd has increased. The two countries measure the statistic differently as Canada reports pigs born and the US reports pigs weaned, but both have increased. Canada's reported pigs per breeding animal has leveled off since 2004 while the US continues to increase. While it is difficult to compare, in 2007 Canada reported 22.3 pigs born versus 18.0 weaned in the US. It is doubtful that there is 24% pre-weaning mortality in Canada to make these two numbers equal.

Figure 3. Change in pigs per breeding herd versus 2000.



The North American pig crop has increased over 12% or near 16 million head since 2000 (Figure 4). Canada posted a higher percentage increase and until 2007 added more total pigs to the supply than did the US.

Figure 4. Change in pig crop versus 2000 (1000 head).



Much of the increased production has gone to exports from both countries as domestic pork consumption has been flat in the US and declined in Canada (Figure 5). Exports have increased in both countries and on a percentage basis much faster in the US (Figure 6). In Canada, export growth exceeded the increase in pork production by 50%. In the US, exports fell 20% short of meeting the increased production.

Both countries will depend heavily on continued export growth if they wish to increase pork production. Population growth in the US and Canada is approximately 0.9% a year. The potential to grow demand lies in tapping new markets as global income increases. This strategy does have risk in the form of higher transportation costs, the strength of the global economy, exchange rate risk, and WTO negotiations.

Figure 5. Change in domestic pork consumption and net exports versus 2000.

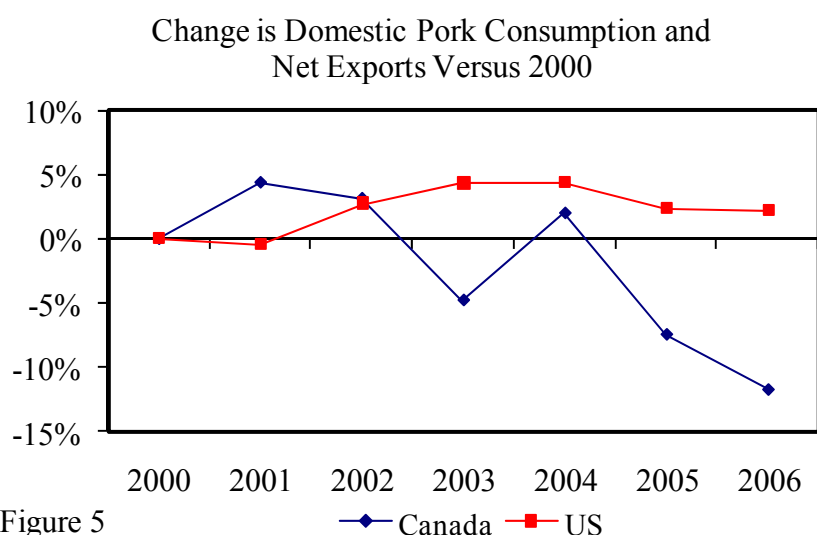
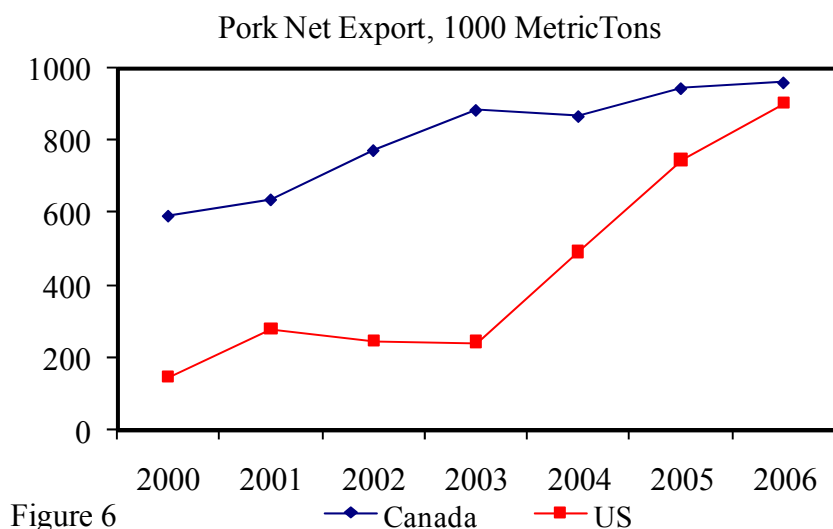


Figure 6. Pork net export (1000 metric tons).



Domestic and export customers are demanding more of their food. These demands are not about wholesomeness, safety from food borne illness, or humane treatment of animals. Those requirements are a given. Demands on food and food producers today are not coming from additional regulations, but rather from customers that have a brand to protect. Organizations with a mission have found that they have a greater impact by attacking the brand than they do by going through legislative channels. Agriculture still has an effective voice in politics and regulation development, but they have less influence with an individual company that chooses to implement standards in order to protect its brand or stock value.

These expectations often deal with animal care, environmental quality, sustainability, fair trade, labor practices and origin. These things have little to do with the science or economics of producing hogs, and everything to do with ethics, trust, and documentation. A good example is country of origin labeling. What started as a protectionist movement by some producer organizations now has taken on new meaning after pets were poisoned by melamine from China. The production sector has traditionally justified its practices based on science and economics. The organizations and individuals pressuring retailers do not care about your economics and may not trust science. Agriculture's defense is often that these additional requirements will drive up the food costs. In the US consumers spend on average less than 10% of their disposable income on food and meat is a fraction of that amount. The vast majority of consumers wouldn't recognize the higher pork prices, and a growing number of consumers are willing to pay a higher price if it fits their preference. The other reality is that some retailers expect the change and expect that they do not have to pay the difference. They see it as a cost of business. As countries try to protect markets for domestic producers and consumers either fear or favor particular characteristics market access will continue to be a critical issue for North American pork producers.

ETHANOL AND CO-PRODUCTS

The 800 pound gorilla in North American agriculture is ethanol. Ethanol and biofuel production is a worldwide phenomena and it is reshaping US agriculture. This new competition for grain and acres has impacted feed prices, feed availability, crop production, and crop input costs.

Ethanol in the US grew out of a perfect storm. Corn growers have supported ethanol production policy for more than 20 years. However, higher world oil prices (nearly a five-fold increase from January 2002 to December 2007), a drive toward energy security following September 11, 2001 and a growing "green" wave pushed ethanol production into high gear. Ethanol has grown up and has its own organization(s) and lobbyists, and the emphasis has shifted to cellulosic ethanol production. US farmers are now more interested in the Energy Bill than the Farm Bill. The 2007 Energy Bill contained a renewable fuels standard of 36 billion gallons by 2022, but "only" 15 billion gallons carved out for grain based ethanol.

A private sector analyst prepared a list of ethanol plants at various stages of production-planning as of August 2007. The industry is dynamic with plans changing with economic conditions in real time, but these figures provide a snapshot of what that sector may look like

in the near future (Table 1). The plants that are producing and expanding last August produced 6.7 billion gallons per year (BGY) and used an estimated 2.4 billion bushels of corn (BBu). The estimated output of distillers dried grains and solubles (DDGS) is 20.6 million tons (MTon). By January the US was producing at a 7.3 BGY pace. When the plants under construction, meaning that they had poured concrete, are included production increases the 11.6 BGY. Adding in those that have broken ground, but had not yet pour concrete, the total was 14.3 BGY. Once these plants are on line it is estimated that approximately 5.1 BBu of corn will be processed into ethanol and over 43 MTons of DDGS will be produced. Plant efficiencies processes may change the corn to ethanol yield and DDGS production, but the ball park will be similar.

Table 1. US ethanol production August 2007: Current and planned.

	BGY	BBu	MTon
Operation-Expansion	6.7	2.4	20.6
Operation-Construction	11.6	4.1	35.1
Operation-Broke Ground	14.3	5.1	43.3
Operation-Planned	36.2	??	??

Note that last summer there were “plans”, meaning announcements in the press or discussions within the industry for plants to total 36 BGY. That is the size of the RFS for 2022 in the Energy Bill and there were plans for that much production three months before it was signed by the President. Also note that there is no estimate of the amount of corn used or DDGS produced to achieve this amount of ethanol. It is currently possible to produce ethanol from cellulose in the lab, but it is not at a commercial scale yet.

The Energy Bill identified a target of 15 BGY from grain with the idea that cellulosic ethanol will be a commercial reality soon and make up the bulk of the renewable fuel production in the US. The 15 BGY and 5 BBu are part of the National Corn Growers 15x15x15 policy. Their goal is to produce 15 billion bushels of corn and 15 billion gallons of ethanol by 2015. They assume that advances in corn yields and ethanol plant yields will leave 10 billion bushels for feed and exports. I see two major challenges. First, the numbers may be right for 2015, but we can build ethanol plants faster than we can change corn genetics in the commercial fields to improve yields. Second, while the incentive structure has shifted to encourage cellulosic ethanol, I am not sure there are dis-incentives for producing more than 15 BGY from grain. Obviously, the price of corn relative to the price of ethanol will act as a governor on the speed of grain based ethanol, but that is little solace to livestock farmers.

The increased demand for corn and resulting higher prices is bringing more land into corn production. In 2007, the US planted its largest corn crop since 1944 at over 93 million acres. But, like pushing on a balloon at one place, something changes elsewhere. Soybean and cotton acres decreased dramatically in 2007. Now the battle is on for acres in 2008 and it is expected that corn acreage may decline from the 2007 level. Reputable climatologists have also placed a 70% chance of a drought in the US Cornbelt in 2008 as well. Bottom line is that corn prices will be higher and more volatile than before, and I include 2007 in the “before” category.

Corn and SBM prices have increased significantly from 2005 and early 2006 level (Figure 7). In January 2006 corn and SBM averaged \$1.88/bu and \$181/ton; in 2008 their prices were \$4.53 and \$336. In January 2006 estimated total cost of production for Iowa farrow to finish operations was \$53.60/cwt carcass. It increased to \$74.70/cwt carcass in January 2008. Table 2 is a simple matrix of estimated cost of production at different corn and SBM prices. Current futures prices adjusted for Iowa basis are predicting costs in the mid to upper \$70s.

Figure 7. Omaha corn and Decatur soybean meal.

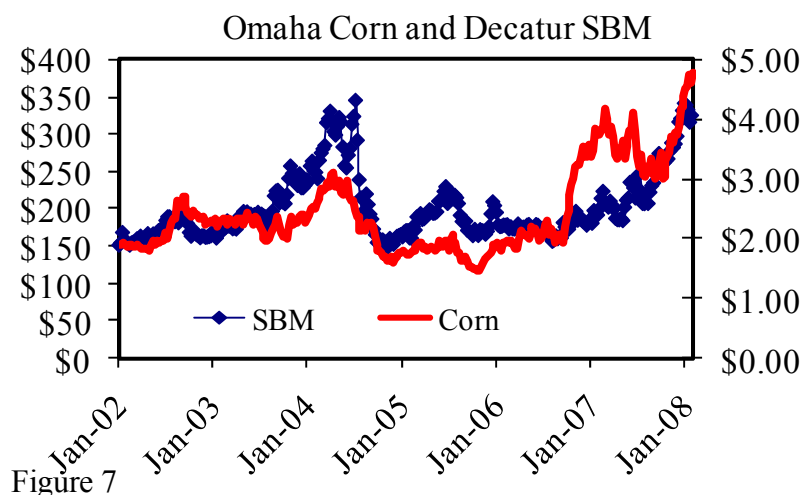


Table 2. Estimated total cost of production for Iowa farrow to finish operations per cwt carcass by corn and SBM price.

SBM/Corn	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25
250	65.59	67.06	68.53	70.01	71.48	72.95	74.43	75.90
275	66.47	67.95	69.42	70.89	72.36	73.84	75.31	76.78
300	67.36	68.83	70.30	71.78	73.25	74.72	76.20	77.67
325	68.24	69.72	71.19	72.66	74.13	75.61	77.08	78.55
350	69.13	70.60	72.07	73.55	75.02	76.49	77.96	79.44
375	70.01	71.48	72.96	74.43	75.90	77.38	78.85	80.32
400	70.90	72.37	73.84	75.31	76.79	78.26	79.73	81.21
425	71.78	73.25	74.73	76.20	77.67	79.15	80.62	82.09
450	72.67	74.14	75.61	77.08	78.56	80.03	81.50	82.98
475	73.55	75.02	76.50	77.97	79.44	80.91	82.39	83.86
500	74.43	75.91	77.38	78.85	80.33	81.80	83.27	84.74

The co-product of ethanol production, distillers dried grains and solubles (DDGS) is an increasingly available feedstuff. However, hogs and poultry cannot use them as effectively as can cattle. The current type of DDGS is readily used in hog diets at 10-15% of the ration and

can replace both corn and SBM. There is evidence that higher levels, particularly beyond 20% of the ration negatively impacts hog performance (Table 3) and fat quality.

Pigs are what they eat and the fat in corn oil in DDGS is more unsaturated than other fat sources and the pig's fat becomes more unsaturated and softer. While there is little fat on the lean pork of today, softer fat is a problem for many bacon slicers.

Table 3. Impact on hog performance and carcass lean of feeding DDGS.

DDGS %	DDGS 0	DDGS 10	DDGS 20	DDGS 30
ADG, lbs	1.90 ^a	1.89 ^a	1.82 ^{bc}	1.78 ^{bd}
Feed:Gain	2.78 ^a	2.78 ^a	2.78 ^a	2.94 ^b
Final BW	257.2 ^a	258.7 ^a	250.6 ^b	246.2 ^b
No. of days	103.5	103.5	103.5	103.5
Dressing, %	73.4 ^c	72.8 ^c	72.1 ^d	71.9 ^d
Lean, %	52.6	52.0	52.6	52.5

a,b Means within row with unlike superscripts differ ($P < 0.05$).

c,d Means within row with unlike superscripts differ ($P < 0.10$).

Source: Whitney, Shurson, Johnston, Wulf, and Shanks, JAS, July 2006.

Producers will trade off some performance if it is economical to do so. However, pork fat quality is a complicated issue. Unlike feed efficiency and average daily gain that belong to the individual producer, pork fat quality belongs to all producers. Packers and processors are raising the biggest concern about fat quality because it disrupts the efficiency and yield of their business. They are finding ways to measure and penalize soft fat. However, if consumers are dissatisfied with pork, they will buy something else. Even if you did not use DDGS, a decrease in pork demand impacts all producers. Unless packers can find a way to effectively identify and signal producers about the appropriate DDGS use, the incentive for individual is to use more than is optimal for the industry.

Corn processing technology to make ethanol is evolving and as it does the co-products will change. There will be improvements in co-products that will allow a larger inclusion rate in hog diets. For example, reducing oil will allow higher inclusion before impacting fat quality. Other technologies are striving to make a corn substitute. Regardless of the changes to DDGS, the markets are efficient and co-products will be priced at what they are worth to somebody. They will be priced at their highest value until that market is filled, then they will be priced at their next highest value, etc. Initially, DDGS were priced for their protein value. Once we had enough protein, their value fell to their corn replacement value. Now that SBM has increased in price so has DDGS value. The bottom line is to not look to corn co-products to be cheap enough to make up for the higher corn price.

Along the theme of priced at their highest value it is important to recognize that once the starch is removed from corn to make ethanol the plant is left with a pile of cellulose with some additional protein and minerals in the form of DDGS. Once researchers crack the cellulosic code, DDGS may be an important feedstock for ethanol production. At a minimum, the ethanol price will put a floor under the price of DDGS.

OTHER OBSTACLES

Higher oil prices that have supported a growing ethanol industry have also led to higher transportation costs of grain and hogs that has implications for some regions more than others. It has also led to higher fertilizer prices and in turn higher values for manure in cropping systems. Production systems and business models that were built on a foundation of cheap oil, cheap corn, and cheap fertilizer are at risk now that these three do not exist. Likewise, production systems in grain surplus regions may not have fully captured these opportunities. Whether it is reducing the carbon footprint to satisfy a retail customer's goal to go green or simple farm level economics, capturing manure value and reducing energy use will be important.

Baby boomers have impacted every facet of society that they pass through. Now that they are reaching retirement the largest segment of our population will be eating less meat. The other demographic shift, at least in the US is the growing Latino population. A recent USDA study found that older people and Latino's consume a below average amount of pork. The demographics are working against pork demand in the US.

Partly related to the demographics above is a pending labor shortage, particularly in the US Midwest. There is evidence that Canada is facing similar challenges. A reduced workforce, at a minimum, leads to higher labor costs. If quality labor isn't available the higher labor cost may come from reduced productivity. Management systems are needed to streamline production practices, provide ongoing professional development for workers, and motivate, retain and grow an effective production team.

MISSION 2050 - RESEARCH AND INDUSTRY INFRASTRUCTURE IN THE YEAR 2050

(A Conceptual Framework)

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“The greatest challenge in the 21st century will be the human-induced changes in the environment “(NRC, 2003).

INTRODUCTION

Mission 2050 is an endeavor to replace the animal research facilities currently operated under contract by the University of Guelph for the Agricultural Research Institute of Ontario and the Ministry of Agriculture, Food and Rural Affairs. The project envisions a complex that has the flexibility to answer many current and future challenges and opportunities that face a majority of the livestock industries in Ontario and elsewhere. The planning has involved various academic and industry stakeholders, and is being discussed with government officials. There is no final master plan that fully accommodates all of the stakeholder needs, but we are continuing to work toward this objective so that the scope of the project can be properly assessed.

MISSION 2050

Mission 2050 (M 2050) will establish a new model of sustainable animal agriculture systems with broad ramifications and applicability at local, regional and global scales. It will establish Ontario at the forefront of agri-food research, innovation and technology development, advancing an agenda of improved sustainability for animal plant ecology systems that flow from the ‘total resource recovery’ approach, with embedded environmental, economic and social objectives. It will serve as an integrated laboratory for the research and development and transfer of next generation primary based ‘eco-products’, ‘green’ technologies and renewable energy systems that will augment traditional agricultural production and provide the economic foundation for the development of ‘next generation’ animal production systems. At Mission 2050, the integration of economic and environmental stewardship objectives will promote sustainable, rural communities in Ontario, through income augmentation, diversification and independence from commodity and energy price fluctuations.

M 2050 is designed as a facility for world-class dairy, poultry, swine- production environmental research, innovation, and new technology development; connecting people and ideas, and a program to create inventive and economically viable opportunities for new

agricultural based industries. The M 2050 program is envisioned as a leading edge research facility designed to bring scientists from many disciplines to converge and work on integrated solutions to rural/urban environmental, social and economic issues.

AN INTEGRATED AGRI-ECOLOGY CAMPUS

As the centre for research on environmentally based, high production dairy, poultry and swine systems, M 2050 will serve as a ‘rural economic incubator’ that links broad areas of agriculture, and ecology with bio-engineering to foster synergistic research opportunities and innovative technology development.

The facility provides a robust backbone of infrastructure along with cutting-edge technologies that facilitates “plug and play” research and the integration of life sciences, bio-engineering and renewable energy investigations.

Unprecedented globally, M 2050 will establish an agri-ecology campus and world’s leading research centre that adopts a ‘total resource recovery’ approach. The planned program focuses on the science and solutions for economic and environmental footprints of animal enterprises, while generating new knowledge in many related fields of research. It will serve as the testing ground for new animal and eco-products, green technologies and renewable farm-based energy that will provide new life to rural communities.

ENERGY RESEARCH / HARVESTING AND FACILITIES

M 2050 will be Canada’s leading research centre for studying and developing the integration of farm-based renewable energy systems, incorporating biogas, solar and wind power production capabilities and will be a net producer of grid based and/or mobile fuel energy. Facilities and infrastructure to develop novel energy, stationary and mobile fuel products will offer innovative fossil fuel replacement products derived from otherwise environmentally problematic organics streams.

Energy research will focus on increased utilization of farm based renewable energy to transform agriculture production systems from a heavy fossil fuel consumer to a net generator of renewable energy. This component addresses the comprehensive system of crop production and energy intensive fertilizer production, mobile energy usage and equipment re-powering with bio-based fuels.

At M 2050, energy, fuel generation and storage technology will be developed that captures and transforms rural geographic and bio-based energy into next generation energy and carbon products. Technology development will occur throughout the animal enterprise, with scalable systems relevant to small and larger scale animal operations. The integration of on-site wind, solar and bio-fuels production optimizes the full on-site potential for green powering in response to diverse and intermittent energy production and demands. Farm based renewable energy will be a key driving force behind creation of these ‘rural economic incubators’.

REDUCING THE ENVIRONMENTAL FOOTPRINT

The primary sphere of focus is the ‘green powering’ of animal operations, resource delivery, crop production, and farm-based renewable energy generation to advance rural social, economic and environmental sustainability, through multidisciplinary research.

Conversion of organics into new products, before they become waste that compromises environmental, human and animal health, presents exceptional research opportunities. Reverse engineering, geared to transformation of waste products through natural processes, allows under utilized resources and nutrients to be turned into new products and novel foods including pharma- and nutraceuticals. Novel industrial bio-products, such as bio-based fossil fuel and fossil carbon alternatives and bio-based energy storage systems yield on-farm direct replacements for imported and transport-intensive fossil carbon products.

At M 2050 research into enhanced utilization of resources, such as feed, water and energy, will result in radical and ongoing reductions of the environmental footprint of animal operations and will transform intensive animal facilities into bio-energy production and ‘rural knowledge centres’ for bio-based products and green technologies.

CO-PRODUCTS FROM ORGANICS

‘Closing the loop’ on environmental organic waste streams means ‘up-engineering’ and ‘reverse engineering’ of resources and nutrients by allowing natural processes to transform problem organics into products. This waste-cycle thinking leads to a paradigm shift that suspends the need to use large amounts of energy, resources and emissions, while stimulating major opportunities for new eco-based technology development.

Renewable animal sourced co-products provide important fossil fuel and carbon-free products for on-site generation of needed crop and animal enterprise inputs, and provide new sources of farm based income through the production of bio-based co-products.

New photo- and bio-reactor technologies that generate specialty industrial oils, pigments, acids, fertigation and other bio-products are further profit centres for direct transfer and use as bio-based fossil fuel and fossil carbon alternatives in industrial green-twinning interconnected systems. Bio- and nutraceuticals can be incorporated on site as novel metabolic modifiers enhancing animal function and productivity. In addition, bio and nutraceuticals represent eco-driven solutions for industrial and urban applications. The E/D 2050 facility will ensure that new advances made by advancing knowledge and integration reach speedy application within Ontario’s farm community and the global marketplace.

EMISSIONS MONITORING / MITIGATION RESEARCH AND FACILITIES

A comprehensive program of emissions measurement, mitigation and sequestration is planned, which addresses the complete cycle of animal feeds production, conversion to milk,

meat or eggs and organics transformation. This includes studies of individual cow, sow, hen and facility emissions and farm-wide emission sequestering.

Creating a pleasant animal environment through solar-based emission sequestration fosters long-term compatibility and coexistence of rural livestock and emerging residential communities. Sequestering noxious emissions proactively provides a healthier environment for animals and staff.

The ‘scalability’ of the renewable energy systems and organics cycling programs developed at M 2050 will have broad applicability to rural Ontario and broad implications for Canada’s multifaceted air quality emission reduction strategies.

MULTIDISCIPLINARY RESEARCH AND PARTNERSHIPS

The integrated nature of the M 2050 facility design provides the conditions and opportunities for broad-based partnerships in interdisciplinary research, entrepreneurship, industrial partnering and collaboration between educational institutions and government. Systems innovations necessary to cluster agricultural, life science and bio-engineering research with technology development and primary companies in the agricultural / animal sector will be developed.

Research facilities are organized in a campus like setting that promotes on-going interdisciplinary collaboration and provides a sense of innovation that will be attractive to leading researchers, diverse partnership, funding opportunities and the public.

Complementing its primary role as a multidisciplinary research instrument, M 2050 will also serve as an active campus for post secondary education, including a full range of environmental and educational programs, technology transfer activities, workshops and field trips. Public outreach and conference facilities are provided to stimulate ‘next generation’ producers, transfer technology to rural and urban communities and provide a unique, environmentally focused public destination.

ANIMAL-SIDE RESEARCH

‘High Performance’ animal design focuses on animal health, comfort, hygiene, productivity, reproduction and operational procedures using state of the art, future-driven facility innovation throughout, with a focus on high quality research and education.

Designed for health and ongoing productivity enhancement, the facility includes a full suite of innovative next generation technologies, to assure contemporary and future relevance in advancing the state of animal science, operational management and achieving sustainable dairy eco-systems. The integration of nanotechnology and digital monitoring assure attention to animal health and quality of food production.

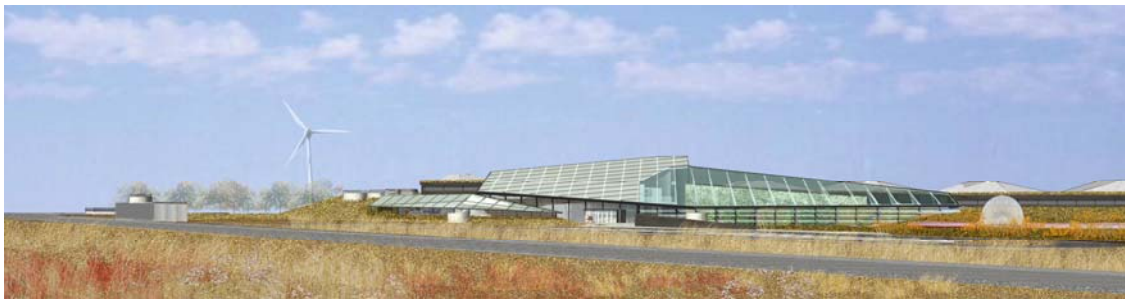
The radial-linked functional components are ensconced in a layered system of bio-security that promotes the participation and interaction of allied researchers without compromising animal and food quality health standards. The dairy herd is managed through the 'Nucleus', which provides for efficient, centralized animal handling, treatment, and segregation, controlled animal flow and exceptional research flexibility.

ANIMAL CO-PRODUCTS

The objectives for development of novel animal products and innovative ecosystem-linked marketing strategies offer opportunities to create new consumer desired products with unique health and sustainable attributes. Neutra-ceutical sourced products and pharmaceutical product development provide opportunities to meet specific diet and health needs.

Development and implementation of small footprint novel products will allow farm-scale production of high value animal-sourced products to meet emerging and future organic-, eco-, health-, and environ-focused markets.

Specialty product generation provides rural Ontario career track opportunities for highly trained technologists and professionals. Rural artisan and specialty products provide an important opportunity for connecting consumers with the culture, science and technology of food production. This instills new confidence in, and support for, rural Ontario sourced animal enterprise centered food, fuel and industrial products.



DEALING WITH OLD AND NEW DISEASE CHALLENGES

PORCINE REPRODUCTIVE AND RESPIRATORY SYNDROME VIRUS (PRRSV): THE DISEASE THAT KEEPS BUGGING US

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ABSTRACT

This is a brief overview of the current situation regarding PRRSV, with an emphasis on information that has appeared in the literature within the last 5 years. This period has been marked by 1) A growing recognition of the high cost of PRRS to swine producers; 2) Continued producer frustration with the (poor) control of PRRS; 3) Heightened interest in regional elimination of PRRSV, but reluctance to proceed without more reliable methods of achieving the objective; 4) Reports (and “counter reports”) of newly emerging, highly virulent, PRRSV isolates; and 5) Innovation in the application of diagnostics to surveillance.

PRRSV CHANGES IN GLOBAL DISTRIBUTION

PRRSV was diagnosed in Africa for the first time in June 2004 following outbreaks in Western Cape Province, South Africa (OIE, 2005a). Steps were taken to eliminate the disease, i.e., quarantine, stamping out, premise disinfection. Serologic tests did not identify additional infected sites at that time, but new outbreaks were identified in October 2005 (OIE, 2005b) and again in August 2007 (Beltran-Alcrudo et al., 2007). A source of the virus has not been determined and remains a point of strong interest.

Chile is on the verge of becoming the first country to eradicate PRRSV. Begun in 2001, by Chilean swine producers organization (ASPROCER) in coordination with animal health government agencies, the national PRRSV eradication program is close to achieving its objective. According to the Chilean swine producers organization (ASPROCER), the last PRRSV-positive pigs were sent to the abattoir on April 2, 2007. Chilean producers are currently in the process of culling all sows that were present at the time of infection (Anon, 2007).

ECONOMICS

The cost of PRRS due to reproductive outbreaks was recognized early in the PRRSV pandemic, e.g., in 1990 Polson et al. (1990) estimated losses at \$236 USD per sow during an acute outbreak of reproductive PRRS due to infertility, abortions, stillbirths, and neonatal mortality. More recently, there is a developing recognition of the cost of PRRSV infection in

growing pigs. Of the \$560 million USD PRRS was estimated to cost U.S. pork producers (Neumann et al., 2005):

- \$250 million USD (45%) was due to declines in average daily gain and feed efficiency in growing pigs;
- \$243 million (43%) resulted from mortality in growing pigs;
- \$63 million (12%) was attributed to reproductive losses.

Estimates in the study were based on feed costs of \$0.286 USD per kg. Since the study was conducted, feed costs in much of the western hemisphere have increased by 50% to 65% as a result of market demand for corn by ethanol manufacturers (Funderburke et al., 2007). Higher feed costs further exacerbate the negative effect of PRRSV on productivity and heighten the urgency to find effective interventions.

TRADE ISSUES

The possible introduction of the virus into PRRSV-free countries via the import of pig meat became a trade issue early in the pandemic. Bloemraad et al. (1994) first reported that virus was present in muscle tissue collected from viremic pigs, albeit at low virus titers, and that the virus was only slightly affected by storage for up to 48 hour at 4°C (39°F). Under experimental conditions, van der Linded et al. (2003) reported that PRRSV "could be infectious through the oral route via the feeding of meat obtained from recently infected pigs." In the field, Margar and Larochele (2004) reported low levels of PRRSV in a small percentage of pig meat collected at an abattoir. When fed raw PRRSV-contaminated pig meat under experimental conditions, some pigs became infected. Several risk analyses were conducted to evaluate the probability of introducing PRRSV through the import of pig meat from PRRSV-infected countries (Banks et al., 2004; EFSA, 2005; Pharo, 2006). Ultimately, the conclusions of such analyses balance on the judgement that extremely rare events may (or may not) occur; events for which probability estimates are often unavailable.

PREVENTION

The objective of prevention programs is either to stop the introduction of PRRSV into negative herds or the introduction of new strains into PRRSV-infected herds (Dee et al. 2001). Animals and semen are the primary sources of PRRSV, but other sources of infection may also be important (Desrosiers 2004). Torremorell et al. (2004) reported that over 80% of new infections in commercial systems in the US were not due to pigs or semen, but to area spread from neighboring units, the movement of pigs in PRRSV infected transports, the lack of compliance of the biosecurity protocols, or perhaps introduction via arthropods.

Recent advances in the area of prevention primarily involve refinements in the area of biosecurity related to the transmission of virus. Otake et al. (2002a) showed that PRRSV was present on workers' coveralls, boots, and hands following 60 minutes of contact with acutely infected pigs. Thereafter, Dee et al. (2004a) demonstrated that elementary sanitation

procedures, e.g., changing coveralls, changing boots, and washing hands, were sufficient to inactivate virus and stop transmission. Likewise, Dee and co-workers have described, tested, and compared protocols involving cleaning, washing, disinfection, and drying that were effective at inactivating PRRSV on transport vehicles [Dee et al. (2004b,c; 2005a,b; 2007) and Dee and Deen (2006a,b)]. In addition, this research group has evaluated air filtration systems intended to reduce the likelihood of aerosol transmission (Dee et al., 2005c). Despite advances in this area, introduction of virus into "biosecure" herds is a problem, particularly in swine-dense areas. Acquiring the knowledge and techniques to reliably protect herds from the inadvertent introduction of PRRSV is vital to future progress.

CONTROL

PRRS control is intended to limit the clinical effects of the infection at various stages of production. As a general rule, control efforts begin by increasing breeding herd immunity, then work progressively toward control in growing pigs through partial depopulation, all-in/all-out pig flow, vaccination, intentional exposure to field virus, or a combination of approaches (Dee, 2003; McCaw, 2003; FitzSimmons and Daniels, 2003; Gillespie, 2003; Thacker et al., 2003). Current methods of PRRSV control were developed early in the course of the pandemic and have been extensively reviewed in the literature (Zimmerman and Yoon, 2003; Zimmerman et al., 2006). New approaches, methods, or protocols have not been described recently.

The major research investment in this area has been on vaccine research and development. Although some producers and veterinarians have reported good results with currently available PRRSV vaccine, it is doubtful that PRRSV control and eventual elimination could be achieved without broadly protective vaccines that reduce shedding and transmission.

EPIDEMIOLOGY AND ECOLOGY

Incremental improvements in understanding PRRSV epidemiology and ecology have been made in recent years, particularly related to transmission.

Pigs are susceptible to PRRSV by several routes of exposure, but the probability of infection by dose differs by route of exposure. Hermann et al. (2005) estimated the infectious dose₅₀ (ID₅₀), i.e., the dose required to infect one-half of the exposed animals, for oral and intranasal routes of exposure at $10^{5.3}$ TCID₅₀ and $10^{4.0}$ TCID₅₀, respectively. Based on data from Benfield et al. (2000), the ID₅₀ for exposure via artificial insemination was estimated at $\sim 10^{4.5}$ TCID₅₀.

Thus, pigs are extremely susceptible to infection via parenteral exposure and much less susceptible by other routes investigated to date. In the field, potential parenteral exposures include standard husbandry practices, i.e., ear notching, tail docking, teeth clipping, tattooing, and inoculations with medications and biologics. Likewise, because PRRSV is present in oral fluids for several weeks following infection (Prickett et al., 2008a, 2008b), normal pig

behavior commonly results in parenteral exposures, i.e., bites, cuts, scrapes, and/or abrasions that occur during aggressive interactions among pigs (Kritas and Morrison, 2004).

Indirect transmission involves transmission by inanimate objects (e.g., equipment, instruments, clothing) or substances (e.g., water, food), living carriers (vectors), or aerosols. Otake et al. (2002b) corroborated needle-borne transmission of PRRSV under experimental conditions. Dee et al. (2002, 2003) showed that PRRSV could be moved extensively in the field on fomites in the field under winter conditions, i.e., below 0°C, but to a much lesser degree during warm weather, i.e., 10-16°C, again illustrating the importance of temperature in virus survival.

Although a complete understanding of airborne transmission has not been achieved, progress has been made. Research in this area is challenging, in part because airborne transmission is not necessarily easily reproduced. For example, transmission from infected to susceptible pigs over a space of 1.0-2.5 meters has been successful in approximately 50% of the attempts (Lager and Mengeling, 2000; Otake et al., 2002c; Torremorell et al., 1997; Wills et al., 1997). In contrast, Kristensen et al. (2004) reported airborne transmission in three trials over a distance of one meter from ~50 acutely infected pigs to ~50 susceptible pigs when 1%, 10%, or 70% of air was exchanged. In a field setting, airborne transmission did not occur over distances of 15 meters (Trincado et al., 2004) and 30 meters (Otake et al., 2002c).

A more complete understanding of the process of aerosol transmission is required if we are to understand the reasons for the observed differences in transmission. Work to date suggests some possibilities. For example, the conditions under which experiments are conducted may affect transmissibility. Herman et al. (2007) evaluated the effect of temperature and relative humidity (RH) on the half-life ($T_{1/2}$) of aerosolized virus. PRRSV was most stable at low temperature and low relative humidity, e.g., $T_{1/2}$ at 5°C and 10% RH was 215 minutes vs. 6 minutes at 40°C and 90% RH. Cho et al., (2006, 2007) suggested that PRRSV isolates may vary in their transmissibility via aerosols, but also acknowledged that the hypothesis requires additional testing.

This is a critical area of research because of its possible role in area spread of PRRSV. The potential for airborne transmission of PRRSV will not be fully understood until additional information is available, including better estimates of the quantity of virus excreted by pigs, the probability of infection by aerosol exposure dose, and the influence of virus strain on aerosol transmissibility.

PRRSV DIAGNOSTICS

Technical developments and improvements in diagnostics are on-going. Innovations include the use of alternate blood collection devices (Broes et al., 2007), blood sampling approaches that do not require venipuncture (Reicks et al., 2006), testing based on oral fluids rather than serum (Prickett et al., 2008a, 2008b), and pen-side rapid assays (Lyoo et al., 2005).

Specific comments must be made regarding PCR-based assays. First, several recent publications document that PCR-based assays provide less than the perfect diagnostic performance we expect. That is, both false positive and false negative results occur with PRRSV PCR-based assays and results may vary between laboratories (Fetzer et al., 2006; Truyen et al., 2006; Wagstrom et al., 2000). Similar observations are not unique to PCRs for PRRSV. Similar observations have been made regarding PCR-based assays for the detection of HIV (Lelie et al., 2002) hepatitis B (Valentine-Thon et al., 2001), and hepatitis C (Shirm et al., 2002).

Perfect tests are not required for the control of PRRSV, but accurate and realistic estimates of assay performance are vital to the interpretation of test results. PCR-based diagnostics will continue to improve, but a critical and independent evaluation of the diagnostic performance of PCR-based assays and on-going improvements in laboratory quality control should be part of the process.

A further PCR-related observation is that PCR-detectable PRRSV RNA appears to be more stable in the environment than had been expected. Under conditions in which infectious virus was inactivated, Hermann et al. (2007) reported that the concentration of virus measured by quantitative RT-PCR remained stable. The implication is that environmental monitoring using PCR-based assays may result in the detection of non-infectious virus and trigger responses not appropriate for non-infectious virus. Further research in this area is needed.

CONCLUSIONS

Despite recent gains in basic and applied science, reliable solutions for the control of clinical losses on farms and the spread of PRRSV between farms have continued to elude us (Kahler, 2004). To date, we have not identified an ecologic weakness in the virus that could be used to control it in our contemporary production systems. Faced with on-going PRRS losses, the general consensus in North America is that PRRSV eradication is the best solution (Burns, 2006). Whether an eradication program could succeed without an "Aujeszky-like vaccine" is a point of discussion, but if we are to proceed, the availability of excellent diagnostics becomes paramount. That is, in the absence of an "Aujeszky-like vaccine", aggressive monitoring based on rapid, affordable, accurate, on-site tests will be the primary tool for the prevention, control, and eradication of PRRSV.

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CONTROL OF SALMONELLA IN THE PORK PRODUCTION CHAIN

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ABSTRACT

Salmonella remains an important foodborne pathogen of concern to public health and therefore, the swine industry. Significant strides have been made at decreasing *Salmonella* contamination in one link of the pork chain, namely, at slaughter and processing. It is expected that standards at slaughter and processing will become more stringent, creating pressure from packers and processors to reduce prevalence of *Salmonella*-positive swine through on-farm interventions. In spite of the widely acknowledged value of controlling *Salmonella* in the live animal reservoir, and copious research endeavors, there is still much to learn about the control of *Salmonella* pre-harvest, as well as discerning the most cost-effective approaches to approaching control in the pork chain. This presentation is focused predominantly on on-farm interventions, as well as discussion of the needs for further information on cost-effective interventions across the pork chain.

INTRODUCTION

Salmonellosis remains a major foodborne disease threat to public health. In the United States, during 1998-2002, *Salmonella* represented the most commonly reported bacterial cause of foodborne outbreaks and illnesses, as well as the second largest etiologic cause of death among bacterial foodborne pathogens (Anonymous, 2006). Although significant strides have been made in reducing the incidence of bacterial foodborne illnesses (*Campylobacter*, *Yersinia enterocolitica* and Shiga Toxigenic *Escherichia coli*) with reductions of ~20-50% relative to 1996-1998 rates, incidence of human salmonellosis has had a modest decrease of only 9% in that same period in the US (Anonymous, 2006). In Canada, the number of reported cases of *Salmonella* for 2004 was 4,953, which represents a decrease from 1998 of more than 50%, but *Salmonella* remains the second most common bacterial foodborne pathogen after *Campylobacter* for those of which swine serve as a reservoir. There is a need to further pursue effective interventions for salmonellosis.

Significant strides have been made at decreasing *Salmonella* contamination in one link of the pork chain, namely, at slaughter and processing. The Pathogen Reduction: Hazard Analysis and Critical Control Point (HACCP) System in the US established performance standards at slaughter and processing plants, which has resulted in decreased contamination of product with salmonellae. It is expected that standards at slaughter and processing will become more

stringent, creating pressure from packers and processors to reduce prevalence of *Salmonella*-positive swine through on-farm interventions.

In spite of the widely acknowledged value of controlling *Salmonella* in the live animal reservoir, and copious research endeavors, there has been little progress in identifying cost-effective interventions for *Salmonella* pre-harvest. Of the potential interventions that have shown evidence of consistent effects in both observational and experimental studies, they predominantly require the producer to incur costs without identifiable direct economic incentive. In addition to effectiveness, there is a real need to identify cost-effectiveness of interventions across all phases of the farm to fork continuum. It is certain that there will be no magic bullet for *Salmonella* control, but an integrated approach that hopefully will result in cost-effective reduction throughout the chain.

POTENTIAL CONTROL POINTS IN THE PORK CHAIN

Humans and Other Animals as Vectors

Biosecurity related practices regarding swine farm personnel and visitors have been associated with decreased *Salmonella* risk for swine. Researchers have found that hand washing and access to toilets and hand washing facilities and the presence of spaces where clothes and footwear could be changed prior to entry into pig areas were associated with reduced *Salmonella* seroprevalence in Danish market swine but were not identified as being associated with *Salmonella* seroprevalence in Dutch herds. It has also been reported that herds with relatively more humans on site daily were at increased risk having high *Salmonella* fecal shedding. Recently, Rajić et al. (2006) reported the unusual finding where if boots were disinfected prior to entry, there was a decreased prevalence of *Salmonella* as compared to facilities in which boots and coveralls were provided—unexpectedly—farms that require shower-in/shower-out procedures were at an increased risk to shed *Salmonella* as compared to farms where boots were provided. These counter-intuitive results are not uncommon in the evaluation of hygiene on farms. Nonetheless, whether personnel hygienic practices are directly related to *Salmonella* risk or whether they simply serve as a proxy measure of a pork producer's overall attitude about biosecurity is unclear, but it does suggest that improved personnel hygiene may be an important intervention for the reduction of *Salmonella* levels. The relatively small cost incurred may be off-set by decreased transfer of other performance impairing pathogens.

The literature is mixed regarding the risk of other domestic species on sight, with few studies finding a positive association. Rodents, birds and invertebrate animals are all known to be potential carriers of *Salmonella*, but their actual risk posed to swine is unclear.

Environmental Contamination

Contamination of the resident environment of animal housing has been implicated in many studies as a source of *Salmonella* infection. *Salmonella* is capable of surviving at least 6 years or more in the environment, and the challenges of cleaning and disinfection of animal

housing are well documented. Mack et al. (unpublished) found that enhanced cleaning and disinfection protocols over standard protocols decreased the contamination of buildings based on aerobic plate counts—but was not associated with decreased *Salmonella* shedding by pigs at the end of the finishing phase. Mannion et al. (2007) recently reported that high prevalence farms tended to have more residual contamination of feeders and equipment after barn cleaning than low prevalence farms, suggesting more stringent cleaning would be associated with decreased prevalence.

Pig Flow

Inconsistency in the hygiene hypothesis: Pig flow practices that are well recognized as important for reduction of production impairing diseases in swine (all-in/all-out pig flow) are often suggested for *Salmonella* control, yet there are few studies that identify that this practice is associated with decreased *Salmonella* prevalence. The biological premise is that the combination of cleaning and disinfecting between groups with age group segregation decreases the potential of *Salmonella* exposure and infection. It has been described that Danish farms that had an area to change clothing and boots prior to entering or leaving the pig area in combination with all-in/all-out production were nearly three times less likely to be seropositive for *Salmonella* than farms that did not have these management practices in place. Farms that had just a changing area or all-in/all-out flow, but not both, did not have a lowered risk. On the other hand, in another study of Danish swine, all-in/all-out pig flow was associated with increased *Salmonella* seroprevalence, although this result was based on a crude odds ratio, not adjusted for other management practices on the farm. *Salmonella* prevalence can be quite high on farms with all-in/all-out production. In a study of US swine farms that were three-site production systems, managed all-in/all-out, the *Salmonella* prevalence in finishers ranged from 0% to more than 70%. A recent report by Rajić et al. (2007) of Alberta swine finishers reported that farrow to finish farms with finishers on-site had lower *Salmonella* prevalence than farms with multiple site production. Furthermore, there was no difference in prevalence between those farms that practiced all-in/all-out flow as compared to those that had continuous flow production. The limited and contradictory evidence in the literature for all-in/all-out pig flow as a means of *Salmonella* control warrants further investigation prior to its recommendation for that specific purpose.

Feed

It is well recognized that animal feeds and feedstuffs can be contaminated with *Salmonella*. It has been demonstrated in experimental settings that animals can become infected as a result of consuming *Salmonella* contaminated feed. There is no doubt that appropriate process control and decontamination steps are needed during feed processing to reduce contamination of feedstuffs in order to avoid dissemination of contaminated feed to herds. There is justification to question the relative importance of the role of contaminated feed in the epidemiology of *Salmonella* on swine farms. Most notably, *S. Typhimurium*, a *Salmonella* serovar often associated with food borne disease in humans is infrequently isolated from feeds in the US or elsewhere. In a multi-country survey in Europe *Salmonella* was isolated from feedstuffs in 17.6% of herds and 6.9% of all samples. Yet, the *Salmonella* serotypes isolated from the feeds were not the same serotypes isolated from pigs on those farms.

Many epidemiological studies have found that pigs fed pelleted rations were at increased risk of high *Salmonella* seroprevalence compared to those fed diets in meal form. This is one of the more consistent risk factors associated with *Salmonella* in observational studies. A recent study by Rajic et al. (2007) in Alberta swine indicated that pigs fed pelleted rations were at increased risk for shedding *Salmonella* as compared to meal diets. Additionally, diets that are acidified either as a result of the addition of whey, organic acids or are fermented have been associated with reduced *Salmonella* prevalence. Conversely, wet, but not fermented, diets have been associated with increased *Salmonella* prevalence. These results with acidification are variable.

Vaccine

A recent systematic review of the literature regarding the efficacy of vaccination to reduce *Salmonella* in live and slaughtered swine was recently published (Denagamage et al., 2007). In general, from a qualitative standpoint, vaccination is associated with reduced *Salmonella* prevalence in swine at or near slaughter. Unfortunately it also highlighted the fact that few published studies were of a quality sufficient to judge internal validity of the projects, decreasing the ability to assess the value of the intervention.

Thermal Environment

Several investigators have reported that cases of human salmonellosis are strongly associated with high ambient temperature in a period ranging from 1-5 weeks prior to the onset of the human case (Bentham and Langford, 1995, Bentham and Langford, 2001, D'Souza, et al., 2004, Fleury, et al., 2006, Kovats, et al., 2004). This suggests that “upstream” factors in the food chain are impacted by high ambient temperature resulting in an increased risk of salmonellosis. Although these upstream factors may include failure in maintaining temperature in the cold chain during processing, shipping and handling by retailers and consumers, it may also reflect risk associated with high ambient temperature on farms that results in increased risk of *Salmonella* transmission and shedding by animals. Previous work by our group and others has indicated that there is an association between season and/or environmental temperature and *Salmonella* prevalence in finishing swine (Christensen and Rudemo, 1998, Funk, et al., 2001). Recent work by our group has demonstrated that 10-12 week old pigs that are cold-stressed and market-age pigs that are heat stressed (18-22 weeks old) are at higher risk to be *Salmonella* positive (Schultz et al., 2007)

Antimicrobial Use

Most research regarding *Salmonella* shedding and antimicrobial resistance subsequent to antimicrobial therapy have been conducted in laboratory facilities involving experimental infection with *Salmonella* (reviewed by Exponent, 2000). In field investigations of the use of subtherapeutic chlortetracycline (CTC) in finishing pigs on US farms, our group has seen no effect (Funk et al., 2006) increased shedding (Funk et al., 2007) and increased shedding (Mack et al., unpublished) associated with the use of subtherapeutic CTC. Impact on shedding may be associated with the antimicrobial resistance profile of the farm's resident *Salmonella*.

Cost-Effectiveness

There is minimal data regarding evaluation of cost-efficacy of different interventions on *Salmonella* control. Goldbach and Alban (2006) Compared 4 strategies for *Salmonella* control in the Danish pork industry: hot-water decontamination of carcasses; sanitary slaughter for farms with high *Salmonella* prevalence; use of home-mixed feeds; and use of acidified feed for slaughter pigs. Only hot-water decontamination had a positive net-present value. Alban and Stärk (2005) modeled the projected impact of different interventions on *Salmonella* on carcasses. The variables with maximum effect on the *Salmonella* prevalence on the final carcass were (1) number of herds with a high prevalence of *Salmonella*, (2) singeing efficiency, (3) contamination and cross-contamination at degutting and (4) cross-contamination during handling. Interestingly, improvement in any one intervention had no effect—several interventions were necessary to achieve the largest reduction, suggesting that at least from the stand point of efficacy; both pre- and post-harvest interventions may be required to achieve decreased carcass contamination. Further efforts on efficacy and cost, as well as policy discussions on what segments bear the cost, are critical to control of *Salmonella* in the pork chain.

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** Where references are not cited, the reader is referred to the review paper by Funk and Gebreyes, 2001 for references. Copies available from the author by email request.

BREAK-OUT SESSIONS

LIVESTOCK BORDER CLOSURE CONTINGENCY PLAN

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ABSTRACT

Many events could prevent Ontario from exporting livestock and livestock products (border closure). These include food safety issues, political/trade issues, disasters and pandemics. The most obvious, however, would be a foreign animal disease (FAD) outbreak in the province.

The closure of international borders to Canadian ruminants and ruminant products in response to the discovery of bovine spongiform encephalopathy (BSE) in Alberta has cost the Ontario economy at least \$945 million². This has led to a real recognition of the vulnerability of the livestock sector to border closure threats.

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) is developing an action plan to be implemented in the event that the border between Canada and the U.S., or another significant trading partner, is closed to the export of livestock and livestock products from Ontario. The goal of the plan is to help maintain infrastructure and maximize the sustainability of the pork and beef production and processing sectors during any disruption to border traffic.

The project has been divided into two stages. In stage one, the OMAFRA team analysed existing plans, and other information, to assess the potential impacts a border closure would have on the economy in Ontario and the livestock production and processing industries. The second stage is underway and involves developing strategies in cooperation with industry to mitigate the impacts.

STAGE ONE REPORT

A summary of the stage one report is available at:
www.omafra.gov.on.ca/english/livestock/general/facts/borderclosuresum.htm

The OMAFRA team made several recommendations. They include the following:

² Statistics Canada, Agriculture Division. (2004). Canada's Beef cattle sector and the impact of BSE on farm family income. (2000-2003), Working Paper No. 69

General

1. A coordinated livestock border closure contingency plan should be developed and would be welcomed by industry.

Prevention

2. Explore options for the prevention of incidents that could cause the border to close. Prevention is the best solution to the potential problem.
3. Promote continued efforts towards improved provincial biosecurity. Consider the development of standard protocols and possible need for regulation.
4. Support the implementation of current and future traceability initiatives.
5. Examine the value of the West Hawk Lake Project and whether Ontario should make efforts to help move this and other potential zoning projects forward.
6. Encourage development of a strategy to develop biosecurity in non-regulated and non-commercial species including backyard flocks and other hobby farm animals.
7. Consider the expansion of training and programs for first responders involved in prevention, biosecurity and mass carcass disposal prior to a border closure.

Communication

8. Maintain communication and a co-operative working relationship with the National Pork and Beef Value Chain Roundtables as they develop plans to deal with a potential market collapse.
9. Investigate the necessary communication and information links with industry and other levels of government that would be needed to deal with a border closure situation.
10. Develop a communications and awareness strategy for the public for border closure issues.
11. Further develop and support direct relationships with U.S. states that import a large percentage of Ontario's livestock with the intent of working towards common trade goals with national authorities on both sides of the border.
12. Develop a communications and awareness strategy for industry (primary producers, processors and related service providers) for border closure issues.

Managing Surplus

13. Review the legislative authority needs of the province to enact orders and strategies for surplus animals in a border closure situation whether resulting from either a FAD or non FAD event.
14. Consider who will take the lead in a border closure incident caused by a non-FAD, as well as the individual responsibilities of both industry stakeholders and government.
15. Develop an action plan with industry to deal with orderly marketing in the event of a border closure.
16. Consider species specific plans for dealing with the impacts of a border closure.
17. Investigate options and strategies for managing surplus healthy animals.

18. Ensure that housing and feeding options for extending on-farm times and delaying marketing for various livestock commodities have been fully explored and documented, keeping in mind animal welfare considerations.
19. Investigate options for managing surplus meat products.
20. Investigate and document proper euthanasia methods for depopulating livestock farms.
21. Encourage completion of a mass carcass disposal options plan.

Processing

22. Investigate the potential limitations to increasing slaughter capacity within the province and whether these limitations can be mitigated.
23. Explore possible solutions to the limitations on additional capacity in the rendering sector particularly as it relates to weekend operation.
24. Consider options should processors or renderers find themselves inside a restricted movement zone in the event of a FAD.
25. Feed ingredients that are currently imported may have to be manufactured domestically. Evaluate whether these ingredients can be manufactured domestically, and if not, why not.

Support Programs

26. Investigate options for business continuity programs from farm through processing in order to help maintain the infrastructure and sustainability of Ontario's livestock sector through a border closure incident.
27. Identify potential financial support for the supply chain to assist in finding solutions to the impacts of a border closure.
28. Investigate the current availability and further need for support services that would help individuals and families through difficult circumstances (both financial and stress related).

Stage 2 of the project will be using these recommendations as the basis for developing a livestock border closure contingency plan.

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PREPARING FOR A BORDER CLOSURE

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INTRODUCTION

In Canada, in 2007, we produced over 31 million hogs. Roughly two thirds (21.1 million) were processed domestically and the remaining third were exported live, mainly to the U.S. Due to our export dependency and perishable product, the Canadian pork industry is incredibly vulnerable to border closure.

MORE NUMBERS

To add scope to our discussion, we need to add numbers. In 2007, Canada exported 996,985 tonnes of pig meat or approximately 83,000 tonnes per month. Should the borders close and Canada be unable to sell on the global market, we as Canadian consumers would be incapable of eating our way through the excess. Due to the perishable nature of pork and limited long term storage options, we would have to dispose of enormous quantities of product.

Even if Canadians managed to double their consumption of pork and Canada had adequate freezer space, the crisis would be far from over since the real issue is animal welfare; the number of live pigs being exported is rising (Table 1). Current practices are very integrated, increasing numbers of very young pigs requiring specialized facilities are marketed in the U.S. (Table 2); should borders close, Canada simply does not have the space to house these animals and within four or five days, difficult decisions including aborting sows and euthanizing piglets will have to be made.

To put the animal crisis in perspective consider the export numbers: on a weekly basis, using data from the week of January 26th, 2008, live hog exports to the United States consisted of: 163,439 feeder pigs; 79,898 barrows and gilts; 9,758 boars and sows.

Table 1. Canada's live swine exports to all countries.

Year	Province		Total*
	Ontario	Manitoba	
2004	3,138,686	4,542,933	8,506,928
2005	2,144,553	5,014,265	8,214,803
2006	2,229,915	5,501,750	8,776,985
2007	2,111,456	6,146,465	10,031,894

*All provinces included

Table 2. Canada's live hog exports, by weight.

Weight	2004	2007
Less than 7 kg	3,087,670	3,808,035
> 7 kg < 23 kg	613,661	679,690
> 23 kg < 50 kg	1,922,163	2,242,054
Greater than 50 kg	2,655,627	3,174,415

ARE WE PREPARED FOR A BORDER CLOSURE?

The short but sobering answer is no. Our vulnerabilities are understood; but short of scaling the Canadian industry back to one that would strictly supply the domestic market, we currently have few tools in place to mitigate the impacts of a border closure.

The Canadian Pork Council (CPC) is working on many initiatives that address different parts of the issue. The CPC has been working through the development and implementation of a National Identification and Traceability program which could help minimize the impacts of a disease outbreak or a food safety crisis. The CPC also has a national emergency communications plan and participated actively in the Pork Value Chain Roundtable's market collapse working group; is a supporter, through the Canadian Animal Health Coalition, of the West Hawk Lake Zoning project; and is a participant in the Canadian Supply Chain Food Safety Coalition's pandemic preparedness activities.

The industry has a lot at stake and needs to become fully engaged in order to find workable tools to help lessen the impact of a closed border. As is often said, it is not 'if' we will face a border closure, but rather 'when'.

BORDER CLOSURE: EFFECTS ON THE ONTARIO FEED INDUSTRY

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Border closure leading to restrictions in animal movement and/or ingredients can occur for several reasons. Similar to a foreign animal disease threat, each border closure can assume its own personality and characteristics. As such, it is difficult and perhaps too cumbersome to develop a plan comprehensive enough to cover all possible contingencies. However, stakeholder awareness and contingency strategy development are needed to mitigate the extensive losses possible. One approach to expose the possible challenges involved is to deal with specific situations such as the closure of the border to the movement of over 40,000 pigs weekly from Ontario to the US.

This discussion will feature more conjecture than detail. The reason is simple. While there have been real-life examples of border closure and their impacts on agri-business, little has been done to prepare or to establish protocols in the event of other closures. Perhaps it is felt that the Federal Government will provide the leadership required. Based on past experiences with foreign animal diseases (FAD) such as the avian influenza outbreak in the Fraser Valley, it is clear that stakeholders in agriculture have to be more involved and work in partnership with the federal government to reduce the effects of such disasters. It is therefore gratifying to see that both the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the Canadian Pork Council (CPC) have established initiatives to mitigate the effects of border closure. It is obvious that the feed industry and animal health providers, as well as anyone involved with shipping and movement of livestock and feed ingredients across borders, need to be involved as well.

The objective of this paper is to assess the possible role that the feed industry could play in the event of a border closure. A basic border closure plan will be discussed, and wherever relevant, comments regarding the impact on the swine industry will be made.

Definition. Within the context of this discussion, a border closure will refer to any restriction to the movement of livestock and/or feed ingredient as a result of a FAD, a pandemic, trade barrier or natural disaster that extends across provincial and state lines, and between western and eastern Canada (at the West Hawk Lake line).

WHAT EXPERIENCE DOES THE ONTARIO FEED INDUSTRY HAVE WITH BORDER CLOSURE?

The feed industry has had direct experiences with border restrictions. The 9-11 terrorist attack created Homeland Security and in turn, the BioTerrorism Act (BTA). Feed was viewed as a bio-terrorist tool, as was any disease such as BSE that could impact both livestock and

potentially humans. With the discover of BSE in Alberta, and following 9-11, any Canadian feed company shipping feed across the border had to face rigorous restrictions and regulations. The BSE crisis led to the restriction of certain ingredients such as tallow, animal-based proteins and vitamin D in any animal feed made in Canada. US feed suppliers did not face any of these restrictions. In addition, any feed crossing the border required the clearance of a CFIA Inspector who had to inspect, approve and sign off on the ingredient list. This negated any last-minute orders plus a payment had to be made to CFIA for this service. The BTA meant that feeds crossing the border were subject to sampling for pesticides, mycotoxins, antibiotics (other than on the label) and disallowed ingredients. Any feed that was sampled could not be fed, and had to be stored (usually at the producer's farm) until the test results came back, a time period of 2 to 3 weeks. The net result was severe delays at the border to get feed to US-based clients and an increase in feed prices, thereby providing a competitive bias to US feed suppliers. With these restrictions, and the rise in the Canadian dollar, the net result was that many companies could no longer afford to ship feed to the US.

Another example of a border restriction was the melamine (and cyanuric acid) adulteration of pet foods that originated in China but came via the US border into Canada. The feed industry had to ascertain that none of the contaminated high protein ingredients (e.g. wheat gluten, soybean meal) used in the pet foods were used in any animal feed. Urea used in ruminant feed and pellet-binders used in feeds for all species were also implicated. Suppliers had to verify their sources and letters of verification had to be written, and some feed ingredients had to be tested for melamine and cyanuric acid. A final example was Star-Link corn. This GM-corn was deemed suitable for animal feed in the US, but not so for livestock in Canada.

For these reasons, any type of border closure has direct economic impact on the feed industry and in turn, on livestock producers. One of the main reasons for a border closure is the outbreak of a reportable or foreign animal disease (FAD).

EMERGENCY DISEASE RESPONSE PLAN (EDRP)

The Ontario Agri Business Association (OABA) recognizes the devastating impacts of a FAD on its' crop and livestock sectors. The feed industry also recognizes that it can be a possible vector for the spread of disease since feed trucks and sales personnel visit many farms. On the other hand, the feed industry has embraced food safety principles through the adoption of HACCP and Good Manufacturing Procedures (GMPs). The emphasis of food safety is on proper record keeping and the establishment of standard operating procedures (SOPs). As such, the feed industry feels that it already has some of the tools necessary to develop strategies to mitigate the spread of disease.

The biggest challenge that exists with a FAD is the 'grey period' where a disease is suspected but not diagnosed. The federal government will assume control when a reportable disease is confirmed. However, this period of confirmation can take up to 72 hours, enough time for a rapid spread of the disease, including across a border. The lack of an Animal Health Act in Ontario prevents any regulated action at the particular farm or location that has the suspected outbreak. Similarly, no compensation programs are in place for a producer who may have to

withhold shipments because of a suspected disease. Finally, a producer may choose not to disclose any information which means that regular traffic can flow on and off that farm. With these issues in mind, OABA has developed an Emergency Disease Response Plan (EDRP) to reduce the risks of disease spread via company vehicles and personnel. Other components of this plan such as insurance for losses and possible liability require development.

POSSIBLE COMPONENTS OF A BORDER CLOSURE PLAN FOR THE FEED INDUSTRY

A Border Closure Plan for the feed industry would just be one component of a larger provincial and federal plan. Several plans appear to exist, and some coordinated approach is required. The question currently is who does the coordination? None-the-less, the feed industry does need to establish some type of framework with the expectation that this plan would be one component of a joint federal and provincial plan.

The following list is specific for the feed industry. It is incomplete but hopefully establishes the groundwork for a more comprehensive plan.

1. Border closure definition –
 - a. Cause and location
 - b. Extent
 - c. Time line
2. Species affected
3. Feeding programs
4. Feed ingredients affected, and alternative sources.
 - a. Product surplus
5. Personnel and Truck movement.
6. Insurance programs.
7. Human toll
8. Risk analysis

1. **Border Closure Definition.** The cause and location will most likely determine the course of actions to be taken, including the duration of any closure. Compartmentalization and zoning, as suggested by the OIE in Europe, is one method of containing disease, and can be a specific definition of a border closure. Other issues need to be considered. If the problem was a disease, did it occur in Canada or the US? Can people, trucks or feed act as fomites to transmit the disease? Can the closure be safely relegated only to certain states and provinces, so that trade can continue between unaffected locations? Could a time line be drawn as to how long the border closure should last? The type of disease will impact on animal movement at the border. Certain diseases would only affect one species, whereas a disease such as Foot-and-Mouth would affect all cloven-hoofed animals. The plan needs to consider and accommodate as much of these permutations as possible.

2. **Species Affected and Transmissibility between Species.** The assumption is often made that for disease situations between the US and Canada, only the non-quota species (beef, swine) would be affected. If a disease such as Foot-and-Mouth occurred, then the impact is on all cloven-hoofed animals, including dairy heifers. In addition and as mentioned below, species other than beef and swine can also be affected if feed ingredients become limiting.

We all know that the Ontario swine industry is extremely vulnerable to a border closure threat. We have a window of a few days before the system become overwhelmed with weaner and growing-finishing pigs. The slaughter capacity for pigs in any disease situation in Canada is very limiting, and feasible solutions are required. Finding a humane slaughter method is also another challenge. If the disease occurred in the US, then the problem is still border closure, but the issue is what to do with healthy, edible animals. The plan has to include housing, feeding and slaughtering contingencies for weaners and growing pigs.

3. **Feeding Programs.** The cattle industry had to deal with a border closure with BSE. Cattle can be placed on back-grounding diets and/or on pasture that will decrease the rate of gain. In Canada, domestic consumption of beef increased. The situation is not the same with pigs. If no market exists for these animals, and slaughter options are delayed, the feed industry would produce diets that are maintenance based rather than production based. Housing would be the bigger issue to consider.

Nutrient requirement data for maintenance of growing pigs do exist, and diets can be formulated and kept as part of the feed industry's border closure plan. However, these diets should be tested with the genetically-leaner pigs of today. In addition, animal behaviour issues would need to be addressed and monitored. Compensation programs would be required to cover the costs for feed, as well as for the housing and maintenance of these animals.

It is expected that some type of humane abortion program would be developed for sows to reduce the flow of nursery pigs on the market.

4. **Feed Ingredients.** In most cases, border restrictions on feed ingredients are expected to be limited in scope, and the challenge would be to find suitable substitutes. However, as indicated with vitamin D during the BSE-crisis, logic is not always used by regulatory authorities. Disruption of feed ingredient flow will likely affect all species of livestock, so all stakeholders should be concerned. In the event of a full blown border closure due to, for example, a pandemic, feed ingredient availability would most likely be far down on the list of priorities. Some border closure plans (Canadian Chamber of Commerce, 2006) propose that movement of certain products across the border would still be necessary, providing that human (and livestock) safety can be maintained. Products such as medical supplies and certain essential ingredients necessary for life would most likely fall under this category. The inclusion of such contingencies within an official border closure plan is necessary at this stage rather than attempting to implement them during an actual crisis.

Ingredients in typical pig diets that would be affected by border closure are indicated in Table 1. Most of the major ingredients are available locally. Some accommodation should be made for those imported ingredients that are essential, and what steps can be taken to maintain an inventory in Canada, or what alternative sources are available.

Table 1: Ingredient availability from local sources (LS), other provinces (OP), United States (US), Europe (E), and Asia, primarily China (A).

Ingredient	Starter	Grower-Finisher	Sow
Corn	LS	LS	LS
Soybean meal	LS	LS	LS
Whey based product	OP		
Porcine plasma	US		
Oat groats	LS		
Herring meal	OP		
Corn distillers solubles		LS	
Canola meal		LS	LS
Wheat, wheat by-product		LS	LS
Soy Hulls			LS
Bakery by-product	LS	LS	LS
Soybean oil	LS		
Animal-vegetable fat	LS	LS	LS
Limestone	LS	LS	LS
Dicalcium phosphate	US	US	US
Magnesium oxide		A	
Salt	LS	LS	LS
Lysine	US, A	US, A	US, A
Methionine	US, E, A	US, E, A	US, E, A
Tryptophan	US, E, A	US, E, A	US, E, A
Threonine	US, E	US, E	US, E
Choline	LS	LS	LS
Zinc oxide	US, A	US, A	
Copper sulphate	US, A	US, A	
Pellet binder	US	US	US
Trace mineral-vitamin pack	US, E, A	US, E, A	US, E, A
Medications			
Other additives			

One key concern is the supply of vitamin and trace mineral premixes. Premix and drug suppliers maintain very low stock levels of these products, so any disruption to border flow can be problematic within a few weeks.

Another impact of feed ingredient shortage is usually an increase in price. For a border stoppage to pig flow across the US border, the ability for feed companies to provide low-cost diets may be a challenge.

Feed ingredient shortages may also impact on certain specialty markets. Antibiotic-free and/or organic diets that are dependent upon ingredients such as essential oils, probiotics etc. may not be possible if these products are restricted at the border.

a. **Product Surplus.** Slaughter of weaner and grower pigs would likely result in the availability of inexpensive porcine meat and bone meal. While alternative uses such as bio-diesel may be explored, feed has always been a useful and nutritious means of recycling this by-product. Poultry diets in Ontario typically contain from 5 to 7.5% meat and bone meal. Research has indicated that levels of up to 25% may be possible in broiler, turkey and layer diets. Re-use of this product is possible at levels of 10 to 15% in grower-finish diets and from 5 to 10% in sow diets (Patience et al., 1995). Though less common since the advent of BSE and with producer and consumer concerns to be aware of, porcine meat and bone meal can be used in ruminant grain diets up to 4% and up to 9% in supplements.

5. **Feed Truck Movement within Restricted Areas.** For a disease situation in Ontario where restricted zones are established, feed companies may need to cooperate to ensure delivery of feed while maintaining biosecurity. An example would be a feed company located within a restricted zone providing feed to one of its' competitor's farms, or the transfer of feed from one truck in a clear zone to another in the restricted zone.

The EDRP Plan developed by the Ontario Agri Business Association covers biosecurity measures for feed trucks and feed personnel during the grey period of a FAD.

6. **Insurance Programs.** No compensation programs currently exist for agri-business in the event of a FAD. Currently, any costs incurred for biosecurity procedures that occur during an alert situation are covered by companies. These procedures include the clean-out of trucks and truck cabs, the use of biosecurity equipment, etc. No compensation is provided for lost business. Costs involved with feed shipments across the border during the BSE crisis and for the BTA were borne by the individual companies. In the event of a border closure, the cost of providing feed to farms deriving no income from livestock has to be covered. The Ontario Livestock and Poultry Council (OLPC) which is leading the way in dealing with FAD challenges is investigating the provision of insurance coverage for livestock producers. Other stakeholders also require similar programs.

Feed companies need to ensure that their liability insurance covers possible claims made for the spread of disease.

7. **Human Toll.** The human impact on livestock producers during any disease or border closure crisis can be overwhelming. Feed company personnel interact closely with producers. Feed is also one of the major cost items on most livestock operations. Situations impacting the welfare and livelihood of livestock producers exact a toll on these service providers.

8. **Risk Analysis.** Cost of the BSE crisis to the Ontario economy has been pegged at approximately \$945 million (OMAFRA, 2007). No estimates are available of what the BSE crisis cost the Ontario and Canadian feed industry. The avian influenza outbreak in BC prompted the closure of two feed mills. Risk analysis is needed not only to provide some estimate of potential economic losses for Agribusiness but also to assist in possible insurance coverage.

The purpose of this paper was to investigate the role that the feed industry could play if a border closure were to occur. One conclusion from this exercise is that there appears to be an urgent need not only for the feed industry, but agribusiness as a whole to develop some type of contingency plan to deal with border closure. Similar to the situation with foreign animal diseases, all stakeholders need to be involved in this plan. The preparation and thought that goes into the plan today would be invaluable if and when a border closure crisis occurs.

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MANAGING PIG FLOW – CONSIDERATIONS AS A BUYER OF WEANED PIGS

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ABSTRACT

Buyers of weaned pigs for wean-finish facilities in the upper Midwest US are looking for the following as they value pigs for their production systems: known genetics, weaned at 21-23 days of age, veterinarian to veterinarian consultations regarding source herd health, defect pigs not included in the shipment, minimal age variation.

BUYER'S CONSIDERATIONS

Movement of Canadian born weaned and feeder pigs to US production facilities is increasing. For the first 5 weeks of 2008, border crossings of pigs >55 kg averaged 148,000 head per week, compared to 115,000 per week for the same period in 2007. With so many pigs being offered to US buyers at a time when high feed grain prices and relative low market hog prices are limiting interest by potential buyers of these pigs, how do Canadian producers make their pigs attractive to potential buyers?

I work as a consultant to many production flows that buy weaned pigs from Canadian producers. In addition, for 27 years at the University of Nebraska I purchased feeder pigs and weaned pigs for use in experiments at the Haskell Ag Lab. Based on these experiences, I've found that weaned pigs destined for wean-finish facilities are worth more if the following criteria are met.

Known Genetics

Buyers of pigs want a prediction of how the pigs will perform in their facilities and how they will grade at the slaughter plant. If the pigs are from a genetic source the buyer is unfamiliar with, data from other buyers of the pigs from this source are very helpful. If possible, supply data from US facilities and US slaughter plants.

Known Health

Buyers of pigs don't want a disaster from a disease they purchased. Many buyers will insist that their veterinarian have a discussion with the source herd veterinarian regarding herd health issues. They are especially concerned that the pigs originate from a PRRS negative (best) or PRRS stable site. They also want assurances of no history of Actinobacillus

pleuropneumonia in the source herd. Does the source herd have a history of pig scours from *E. coli* or other organisms that will result in pigs having diarrhea within 3-5 days after arrival?

In many instances, buyers are asking the source herd to vaccinate the pigs just prior to or at weaning with products approved for use in Canada. Depending on the vaccine, buyers may pay for the cost of the vaccine with the seller assuming the labor cost for administration of the vaccine to individual pigs. Many buyers want to know what the breeding herd health protocols are as further verification of the health status of the purchased pigs.

Older Weaning Age

While the current weaning age in the US and Canada is averaging 19 days of age, buyers of pigs prefer older pigs since age and arrival weight of the pig at the wean-finish facility are related. The challenge is that many contracts for purchase are based on a 10, 11 or 12 pound weights with a 'slide' of only \$0.75-1.00US per pound for over or underweight load average weights. The slide was originally developed as a way to compensate both parties for the estimated cost of gain during the period shortly after arrival in a facility. This cost of gain has increased with the increase in feed ingredient prices and buyers are recognizing this. Based on the results of Main et al. (2005), producers have begun requesting pigs with an older weaning age, especially if they can pay for the heavier pig weight using the price slide just described.

Large Lot Sizes

Many production facilities in the US are sized with rooms of 1000- 1250 pig spaces. Buyers of pigs destined for these facilities struggle with management of the first diets fed to pigs in terms of matching the feed budget to the age of the pig. This becomes more of a problem as the age variation or the number of days required to fill the space/room increases. Generally the last pigs delivered to the room are at a nutritional disadvantage due to difficulties in managing the feed budgets when there is only 1 feed bin per row of feeders and the oldest pigs are due to change to the next diet in the budget, which is always lower in cost. Large lot sizes become even more important if the buyer is double stocking the wean-finish facility.

One method being used by sellers of weaned pigs to increase lot size is to switch from weekly farrowing to batch farrowing. I have worked with one producer in Nebraska who has 350 sows and farrows 56 litters once every 4 weeks. This allows him to deliver 500+ pigs at a time to the buyer. In this case, the long term agreement is structured around 500 head pig nursery and finishing rooms to match the delivery flow. The challenge for the breeding herd is the variation in intensity of labor with the 2 week period following weaning being very intense with both breeding and farrowing activities and 2 weeks with relatively reduced labor needs. Another challenge is the slightly increased female inefficiencies due to females that recycle or return to estrus at irregular intervals not fitting into the desired breeding period.

Minimize Defective or Rejected Pigs

No one likes to euthanize pigs. However, buyers of pigs will generally grade the pigs at arrival and sort off pigs with known defects, such as ruptures, swollen joints, lumps, weights

less than 7 pounds (or 6 or 8 pounds, depending on the contract agreed to), etc. These pigs are often graded as 'no value' and euthanized. If the buyer has 1250 spaces to fill, purchases 1250 pigs for these spaces and ends up grading out 50 pigs at arrival (4%), this means he is short 2 pens of pigs if the facility has pens designed for 25 pigs/pen. In addition to not having the number of pigs intended, the cost of disposal of the euthanized pigs becomes a production expense for the buyer.

Time of Delivery

While most production sites prefer to wean in the early morning hours, this often means that the pigs arrive at their US production site during late evening hours, or on Saturday morning in the case of Friday morning weaning. The ability to load transport vehicles with weaned pigs at alternate times such that the arrival at the production facility is more favorable to the buyer of the pigs may be worth a small incentive.

CONCLUSIONS

Weaned pigs from Canada have become an important source of pigs for many wean-finish facilities in the upper Midwest. Depending on the outcome of the joint House-Senate Conference Committee discussions regarding implementation of COOL (Country of Origin Labeling) as part of the 2008 US Farm Bill, the flow of pigs may be interrupted for a period of time as buyers of pigs react to slaughter plant requirements for documentation of the origin of pigs. However, the quality of the pigs traditionally delivered, when combined with the very large demand for large lot sizes of pigs means the demand can be expected to continue.

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OPTIMUM PIG FLOWS

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Producing the optimum number of pigs from your unit is essential in order to maximize profits and produce as efficiently as possible.

It is well proven that there are many aspects of pig flow that influence the performance of your barn:

- Increasing weaning age cuts feed cost to market.
- Overcrowding causes drops in growth rate and increase in vices.
- Under capacity results in empty space which is expensive.
- Feeding the wrong rations might slow pigs down and cause constipation in the barn.
- Deterioration in health or acute health challenges can result in lower growth rate or, in some cases, empty space from high mortality.

The whole production system should be geared to producing the “right” number of pigs.

Producers need to clearly understand the economics of different alternatives when deciding what number of pigs is “right” for their barn.

There is a good case for producing the maximum number of pigs out of the sow unit, as most costs are fixed on the weaned pigs. However cutting the age at weaning might result in a less profitable system due to higher feed costs to get the pigs to market. This is especially true when pig markets are low and feed prices are high as they are at the present time. Most nutritionists are now advocating a weaning age of at least 20 days.

There is nearly always a slow down in growth rate in the summer time. Loss of appetite due to heat causes pigs to get backed up and barns can become constipated. This often results in producers having to sell lighter slaughters at a time when the price is traditionally at its peak.

This can be avoided by selling feeder pigs in the late winter and early spring when the market for isoweans and feeder pigs peaks. That way you can create extra space in the system to spread pigs out for the summer months and prevent excessive congestion in the barns.

Alternatively if extra contract space is available, producers can take on extra space in the late spring in anticipation of the congestion and avoid selling pigs lighter than desired.

By the same token, there is often a lack of pigs in many systems in winter when the productivity in the sow units drops due to summer infertility and heat stress on boars. It is essential to monitor this over several years so that producers know how many extra sows need to be bred in order to avoid fluctuations in pig flow.

Maintaining good health in the barns is also essential. Disease breaks inevitably cause a slow down in growth and increase in mortality. If there is no associated mortality, but the pigs just get sick, then barn constipation occurs. By contrast, excessive mortality, as in the case of Circovirus can leave expensive space empty.

I suspect that health, or rather the lack of healthy pigs, is the most underrated cost in many systems. We estimate that PRRS alone in the finishers, even with the absence of other diseases costs producers about \$4.50 per pig. This is from our assessment of about 350,000 pigs through our finishers in the US.

Maintaining strict biosecurity protocols in both the sow barns and grower units is essential.

Monitoring gilt source and semen source is your veterinarian's responsibility.

Make sure you maintain biosecurity in the grower units so as to avoid unnecessary and costly health breaks.

In addition, managing sick pens is essential. It is always the strongest and healthiest pens that do not get sorted down causing overcrowding and drops in growth rate for the best pigs.

Why do we give the least healthy pigs the most room? Producers need to make decisions very early on whether to cull or destroy sick pigs in order to use space efficiently. It is very seldom cost effective to sell cull pigs versus destroying them. Transport costs alone can be more than producers receive for the pigs. Better to bite the bullet and use the space for healthy pigs.

There is certainly merit in simply putting pigs in pens according to how they arrive instead of sorting by size. Pecking order is established quickly and as the fastest growing pigs reach market weight, they leave behind extra space for the other pigs to grow on.

In conclusion, it is essential to know what the opportunity cost of taking one course of action is over another. Running a production system is not just about producing the most pigs possible. It is more about producing pigs as efficiently as possible.

INSURANCE BASED RISK MANAGEMENT FOR SWINE FACILITIES

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What causes one barn to burn while another of the same style and construction era remains standing forever? No one really knows. Generally the only thing left after a barn fire is a smoldering heap of wood, ashes, steel, concrete and dead animals. The lack of eye witness accounts and the total devastation of the structure often leave fire experts such as the Ontario Fire Marshal and insurance adjusters scratching their heads to determine the cause.

There can be many causes for a barn fire: lack of maintenance, electrical problems, heat lamps, corrosion of components, methane gas explosions, but pinning the cause on one of these is difficult. Often when a fire destroys a barn the cause of loss is categorized as “unknown origin – suspected electrical.”

So how can barns be made safer, and less prone to fire? When it comes to swine confinement facilities there are some very specific steps that you can take to ensure that your barn is less prone to fire.

The first step is to always ensure that you have working fire extinguishers inside the building and that they are maintained on a regular basis. It may seem like a simple thing, but often fire extinguishers are not maintained inside barns, and if they are in place, they become good spots to hang items such as clothes, hats, or extension cords. Fire extinguishers should be mounted in all areas of the barn, but should also be present in some very specific locations. These locations include: by the electrical panels, near feed mixing rooms, inside mechanical rooms, and close to every door that separates one area of a barn from another. Ideally there should be one fire extinguisher mounted permanently to the wall every seventy-five feet throughout the barn.

The next step you can take to make sure that your barn is less prone to fire is to always ensure that spec-grade electrical equipment is used within the barn, specifically when it comes to receptacles. Spec-grade electrical receptacles are specially designed electrical receptacles that meet demanding specifications. Spec-grade electrical receptacles are generally similar to ordinary residential use electrical receptacles except that the terminals are fabricated from high strength copper alloys instead of ordinary copper alloys such as 70/30 (70% copper, 30% zinc) cartridge brass.

Manufacturers must use the higher strength alloys because terminals made of lower strength alloys can become overstressed and will fail to adequately secure an electrical plug which is inserted. Since the materials used to construct the receptacle are of a higher grade, the gases that are found in most swine confinement buildings will not attack the components as quickly

and could extend the life of the receptacle. Remember though that, as with most items found in a barn, the spec-grade receptacles will still need to be maintained on a regular basis.

This brings us to the second step – Maintenance. Maintenance of the systems within your barn is very important. These systems include the structure itself, the plumbing system and the electrical system. Many people forget that their electrical system needs to be maintained on a yearly basis, just like any other piece of equipment on your farm. Regular maintenance by a qualified electrician can save you money and headache when something breaks down at an inconvenient time. Having an electrician inspect the system to look for problems with the wiring or for signs of overload is a critical factor in maintaining your barn.

As well as maintaining the electrical system, you should also inspect both the plumbing system and the building itself. The plumbing system will not cause your barn to burn, but it should be included in a yearly inspection of the premises. Part of that yearly inspection should be a thorough review of the condition of your barn. Look for areas where there is a build-up of dust or debris and clean it. Look for weak or damaged trusses or areas where there may be impact damage to poles or beams. Also look for areas where material has been stored against heating devices, or where material is blocking access to electrical panels or disconnects.

The heating systems in your barn are also critical components that could lead to a fire if they are not maintained or if they were installed incorrectly at the design stage or after they have been repaired. Maintenance of your heating system will benefit you in two ways. First, a properly maintained heating system operates more efficiently thereby saving operating costs. The second benefit is that a properly maintained heating system may lead to a decrease in risk potential for a fire. Insurance inspectors often highlight problems associated with heating systems. The list of problems noted include; missing heat shields, units installed too close to combustible materials, debris around boilers, unit heaters with rotten or damaged jack chains, damaged gas or propane lines to the heaters. Money spent to maintain your heating system by a qualified individual is never wasted. Often we see heating units that have been modified or repaired in such a way as to make them extremely dangerous. Maintaining your own equipment may seem like a cost savings, but the reality is that heating technicians are trained to look for problems that may not be apparent with your system.

Maintenance of the barn also brings about new risks that you may not have thought about. Whenever welding or cutting is carried out inside a swine barn there is always the possibility of a fire starting, either at the moment the work is being done, or later due to smouldering ignition of materials near where the work was completed. The development of a hot work permit may help to reduce the likelihood of a loss. With a hot work permit, all of the employees in the barn are made aware of the requirements that are set in place before the welding or cutting begins. Most insurers have developed these programs themselves for use by their policyholders or will help you develop a specific program for your barn.

A thorough inspection of the attic is also warranted on a yearly basis. When you are in the attic, look for signs of water or mold damage. The underside of the roof should be carefully inspected to ensure that moisture damage has not occurred. If the attic is humid, a thorough

inspection of the gusset plates on the trusses can help to point out areas of concern. Rusted gusset plates are a sure sign of a humid or wet attic and that problem needs to be dealt with immediately. If you have gusset plates that are rusted or corroded, a qualified builder should be contacted to determine how serious the problem is and what potential solutions there may be.

All newer barns are required to have fire separation walls in the attic. This wall should be inspected to ensure that there are no breaches in the wall. Often openings are cut in these walls when access to certain parts of the barn is needed and are then not sealed. The fire separation wall in the attic may not appear to serve a purpose due to its design, but it will slow the spread of fire through a structure and must be maintained in order to provide this level of fire prevention.

If you are thinking about building a new barn you should consider the installation of actual fire walls that are designed to prevent a fire from escaping from the compartment that it is designed to protect. By design, all swine barns could easily be constructed with a two hour fire wall that would separate the building along the natural breaks that exist between barn sections. The additional cost of the firewall during the construction phase is a small price to pay to protect your investment in the structure, the animals and your future. Although a fire wall is not required by the current building code, there are insurers that mandate the use of these structures and base their rating on the presence or absence of them.

Another area of concern in some older swine facilities is sprayed in place polyurethane foam insulation and exposed foam insulation such as Styrofoam SM™. The risk potential for a total loss fire increases quickly when there is exposed foam, and underwriters and loss prevention personnel will often point out the foam and ask for it to be covered. These types of insulation are extremely flammable and if they are not covered by some form of fire barrier or intumescent paint they pose a great risk to the structure and although they may not be what causes a fire they add a substantial fire load to a building. Although the building and fire codes allow you to have the unprotected foam insulation in an agricultural building, many insurers will require that the foam be coated with a fire retardant or that it be covered with a non-flammable coating.

You may not think that barn operation could impact the likelihood of a fire in a building, but it can play a huge role and has been instrumental in several large swine facility fires in the last year. In the last couple of year's methane gas explosions and fires have become a disturbingly normal occurrence. For a methane gas explosion to occur several factors must occur in just the right set of circumstances, and the exact nature of what happens is purely speculation since no two fires are identical.

With that said, some factors appear to be common in these types of fires and explosions. First they seem to happen mostly in pit ventilated barns, and when the barns have been left empty between crop cycles. Methane gas appears to have built up inside the closed building and when the heaters are turned on again the methane mixes with the oxygen in the air until it reaches its upper explosive limit and then ignites due to the presence of the open flame heater.

The methane burns at the ceiling and if there are any flammable materials there, they readily ignite.

By being aware of the presence of (or the potential for) methane gas to build up within a barn, farmers can take precautions that could save their building. The first step is to not shut the heat off and close up the building when there are no animals inside. Leaving the heat on and keeping your fans running prevents the methane from building up to explosive limits. The second thing you can do is to vent the building prior to turning on the heaters after the barn has been idle. This will vent the gas from the building and should keep the level of methane below the lower explosive limit.

The steps listed above are best management practices, and are intended as a guide only. Many insurance companies have qualified loss prevention staff as part of their risk management team and they are an incredible source for information regarding fires and loss prevention on the farm. If you have any questions, be sure to ask your broker or agent if your insurer has access to fire prevention information.

RISK MANAGEMENT FOR FARMS

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Regular maintenance on all aspects of your farm is important. When you do repairs to your vehicles and farm equipment you should also do maintenance to your farm buildings.

The electrical system in your barn is the most forgotten part. If it works leave it alone is the wrong attitude to take. All parts of your electrical system need to be checked at least once a year. There are miles of wire in your barn, most of which isn't easily seen. Everything that uses hydro will generate heat. Loose connections will make this worse. With the conditions (water and gases) in hog barns, corrosion is common for most electrical parts. I have had 2 large hog operations test corrosion resistive receptacles. It is now a recommendation from Manitoba Hydro to the Canadian Electrical Code to make this a code change. Proper surge protection is very important with all the electronics. Clean Volt is a filter that prevents lightning and spikes in voltage. There is also protection available for your telephone lines to protect your alarm system.

A proper alarm system is a very important tool for protection and peace of mind. There are some alarm systems that are much better than others. Alarms should have high, low temperature settings. These settings should be adjusted as the seasons change. The alarm must also indicate power failure.

Most alarm systems only monitor one phase of your hydro system therefore it is important to install a phase relay. This is easily installed at a small cost by your electrician. Alarm systems should be tested regularly and logged. Batteries should be changed twice a year.

A proper size generator is important to the life of your livestock. Your generator should be tested monthly under load conditions. This testing should be logged and yearly maintenance done. The generator must be properly hooked to the electrical system with a transfer switch. A PTO generator is fine but a tractor large enough to run it must be on site at all times. It is important that more than one staff member knows how to operate the generator.

The heating system in your barn must be serviced annually by a qualified contractor. I have been suggesting electrical grease called Nolux (or a similar type) be installed on the electrical wiring of the box heaters. This service work is suggested to be done before the heating season.

A Rodent program is important to the biosecurity of your operation. If you have rodents there is no biosecurity. It is recommended that a Pest Control company come in to set up your program. They will locate the bait stations in the proper locations. Then you can maintain

your own program. It is recommended that you log the activity of the bait stations monthly and change the type of bait quarterly.

Fire extinguishers are a must. They should be located at all mechanical areas. They should also be located at each exit from the barn and every 75 feet in the hallways. Everyone working in the barn should be trained on the use of a fire extinguisher. Your local fire department should be familiar with your operation. A farm visit is recommended by the fire department. A diagram of your farm's critical points should be available to the fire department.

Welding repairs should be done outside of the barn when possible. When this is not possible they should be done in the morning. Someone should stay in the area for at least an hour. This area should be checked before lunch and at the end of the day to make sure there are no hot spots.

Fire walls should be hollow concrete block or poured concrete with parapet above the roof and past the side walls. All openings in the wall must maintain the same rating. It is recommended that a two hour rating be maintained.

USING DRIED DISTILLERS GRAINS WITH SOLUBLES (DDGS) IN SWINE DIETS

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INTRODUCTION

The rapid expansion of the North American ethanol industry has resulted in a large increase in the price of cereal grains. Grain prices have been further fueled by low yields of wheat due to droughts in certain parts of the world. Crop farms have historically produced grain crops for food for people and livestock. The ethanol industry is adding a third major use. With the large increase in feed costs we have experienced in Canada in recent months it is important we consider and optimize the use of alternative ingredients if we are to keep our feed costs in check. Dried Distillers Grains with Solubles (DDGS) is one such product and a co-product of ethanol production. As the ethanol industry in North America has expanded, there has been a subsequent increase in the production and availability of DDGS.

DRIED DISTILLERS GRAINS WITH SOLUBLES (DDGS)

Cereal grains including barley, corn, rye, sorghum, and wheat can be used for producing ethanol and subsequently DDGS, however, corn and more recently wheat have been the major grains of choice for ethanol production in North America. The interest in DDGS is mainly due to the three fold increase in the concentration of nutrients (protein, fat, vitamins and minerals) in the DDGS compared with its parent grain, which could potentially make DDGS a better feed ingredient (Table 1). The nutrient profile of corn DDGS is quite different from wheat DDGS. Corn DDGS contains more fat, while wheat DDGS is higher in crude protein. Some considerations to take into account when purchasing DDGS:

- Quality and consistency of the final product.
- Ease of handling (loading & unloading) and transport.
- Incidence of mycotoxins – Is the plant testing & frequency.
- Nutrient profile of DDGS – Total fat, protein, fiber content, etc.
- Amino acid content and availability.
- Know plant where sourcing from – All sources are **not** the same and there can be large differences between sources in nutrient content and value.

Nutrient Composition of DDGS

Dried Distillers Grains with Solubles (DDGS) is a source of protein, energy and available phosphorous to swine diets and will replace a portion of the grain, protein source(s) and supplemental phosphorous. It is important to remember that the DDGS products are still

evolving, which emphasizes the importance of knowing the source you are using as it is likely produced from new ethanol plants is a much different product than sources produced from older generation plants 3-5 years ago. In corn DDGS, the crude protein can range from 22 to 32%, while total lysine ranges from 0.40 to 0.99%, whereas in the wheat-based DDGS, the crude protein ranges 23 to 37%, while total lysine ranges from 0.49 to 0.94% (Payne, 2007). If we look at the amino acid availability for corn DDGS and specifically lysine which is the first limiting amino acid for swine, we observe a large range in lysine digestibility between sources (Table 2; Stein, 2006). The variation in lysine content and digestibility can be attributed to a number of factors: 1) Variation associated with parent grain due to variety, regional or environmental differences, drying and storing. 2) Perhaps the most significant reason is the variation in the drying process from one plant to the next for the DDGS. Drying temperature can range 120 to 620 °C and if not controlled effectively, over-heating can cause significant damage and renders lysine and other heat susceptible amino acids unavailable to the pig post digestion.

Table 1. Nutrient profile of wheat, wheat DDGS, corn, and corn DDGS as fed.

Item	Wheat	Wheat DDGS ¹	Corn	Corn DDGS ¹
Moisture, %	12.0	9.8	11.0	11.9
Protein, %	13.5	35.0	8.3	27.2
Fat, %	1.9	6.0	3.9	9.5
ADF, %	4.0	13.6	2.8	9.9
NDF, %	13.5	33.1	9.6	25.3
Total lysine, %	0.34	0.90	0.26	0.85
Av. phosphorous, %	0.19	0.39	0.04	0.52
ME, Mcal/kg	3.21	2.97	3.42	3.34
NE, Mcal/kg	2.54	2.00	2.73	2.45

¹ New generation ethanol plants.

The low digestibility of lysine is often associated with low analyzed total lysine in the sample. Calculating the lysine to crude protein ratio gives an estimate of the quality of the lysine in the sample. If the lysine to crude protein ratio is 2.80% or greater for corn DDGS then this sample has an average or above average quality, but if the ratio is lower than 2.80%, then it has reduced quality. Because lysine is usually the first limiting amino acid in diets fed to swine, corn DDGS samples with a lysine to crude protein ratio that is less than 2.80 should not be used in swine diets. Because wheat DDGS is a relatively new product there are few published reports that provide estimates of amino acid digestibility for swine and those available are with product from older generation plants that may not be representative of product available today from new generation plants.

Table 2. Concentration and digestibility of crude protein and amino acids in 36 samples corn DDGS.¹

Item	Average	Standard ileal digestibility, %			
		Average	Low	High	CV
Crude protein, %	27.5	72.8	63.5	84.3	7.32
Lysine, %	0.78	62.3	43.9	77.9	12.2
Methionine, %	0.55	81.9	73.7	89.2	5.0
Threonine, %	1.06	70.7	61.9	82.5	7.4
Tryptophan, %	0.21	69.9	54.2	80.1	10.0
Isoleucine, %	1.01	75.2	66.5	82.6	6.3
Valine, %	1.35	74.5	65.8	81.9	6.3

¹ Stein, 2006.

The digestibility of phosphorous in the DDGS is greater than in the parent grain and may be a result that some bonds that bind phosphorous to the phytate complex in the parent grain have been hydrolyzed during the fermentation process in the ethanol plants, which makes more phosphorous available for absorption. If DDGS is included in swine diets this reduces the need for supplemental inorganic phosphorous and decreases the amount of phosphorous that is excreted in the manure. Because of the variation among sources of DDGS it is recommended that producers examine the concentration of nutrients in the product before buying DDGS. A suggested check list for corn DDGS is outlined in Table 3 (Stein, 2007). In addition it is recommended that assurances be sought for the absence of mycotoxins in DDGS before it is purchased.

Table 3. Checklist when buying corn DDGS.¹

Item	Minimum	Maximum
Crude protein, %	27.0	-
Fat, %	9.0	-
Phosphorus, %	0.55	-
Lysine	2.80% of crude protein	-
ADF, %	-	12.0
NDF, %	-	40.0

¹ Stein, 2007

Feeding Recommendations for DDGS

Many feeding trials have been carried out over the past 5 years with corn DDGS in the US to determine the maximum feeding level for different ages of swine. We conducted a grow-finish feeding trial at a commercial research barn in Iram, AB with corn DDGS sourced from a new generation ethanol plant in Minnesota (Table 4). The feeding trial found we could feed up to 25% corn DDGS from this new generation ethanol plant and achieve similar biological performance as with a typical Western Canadian diet without corn DDGS.

From a number of research trials with corn DDGS compared to a corn soybean meal control diet it is suggested that yield or dressing percent declines 0.3% for each 10% corn DDGS included in the diet. It is believed that the higher fiber and/or excess protein in the diet with the increasing DDGS levels in the diet are involved with the reduction in dressing percent. Some more recent trials are investigating the impact of removing corn DDGS from the diet 4-6 weeks before marketing in an attempt to mitigate the impact on dressing percent. Thus, it is important that this be taken into account when calculating the net return to using DDGS and in the decision whether to use DDGS. As a lot of the feeding trials were conducted using corn DDGS sourced from different ethanol plants with some major differences, corn source, old vs. new plant (technology), drying process, etc. many of the feeding trials come up with different feeding recommendations.

For the most part if the corn DDGS source is purchased from a plant which is taking due care sourcing good quality grain, have a controlled drying process of the DDGS, where regular nutrient analysis and mycotoxin screening is being conducted the following are suggested feeding levels: Late nursery 10-15%, grower and finisher 20%, dry sow 20-25%, and nurse sow 10-15%. Because of the severe negative long term impact mycotoxins can have on sow reproductive performance it is recommended that regular screening for mycotoxins of DDGS be conducted to ensure mycotoxins are absent or at very low levels. It is very important that producers choose carefully when sourcing DDGS as quality varies from plant to plant. In addition if you are purchasing DDGS through a broker that you know the plant where the DDGS is being sourced from and the broker is clear that he needs to receive approval from you or your nutritionist to change source.

There is not a lot of research information here in Canada on feeding wheat DDGS to swine. Some of the initial studies have been conducted using wheat DDGS with reduced protein quality and suggest that increasing levels of wheat DDGS may reduce feed intake and growth performance (Thacker, 2006). For some of these trials diets were not formulated on a NE and digestible amino acid basis, which may have contributed to the reduced growth performance. Contrary to this research from the Netherlands (Cited by Zijlstra, 2007; Smits, 2007, personnel communication) with diets formulated on a NE and digestible amino acid basis using high quality wheat DDGS found that they can include up to 15% in the diet with no impact on performance. We expect that wheat DDGS sourced from new generation ethanol plants which have taken due care in sourcing good quality wheat, and have a controlled drying process for the DDGS will produce a good quality DDGS. However, it will be important to characterize the quality of the source before using.

Table 4. Effect of feeding increasing levels of corn DDGS on grow-finish performance in a commercial facility.

Item	Corn DDGS, %						SED	P <	
	0	5	10	15	20	25		Linear	Quad.
Pig weight kg, day									
0	36.9	37.0	37.0	36.9	36.9	36.8	0.15	0.35	0.19
53	87.6 ^a	89.8 ^b	89.0 ^b	88.9 ^b	90.1 ^b	89.6 ^b	0.60	0.01	0.15
Day 0 to 53									
ADG, kg/d	0.936 ^a	0.975 ^b	0.964 ^b	0.958 ^{ab}	0.972 ^b	0.967 ^b	0.0118	0.05	0.14
ADFI, kg/d	2.33	2.41	2.36	2.29	2.38	2.31	0.029	0.12	0.48
F:G	2.49 ^a	2.47 ^a	2.45 ^a	2.39 ^b	2.45 ^a	2.39 ^b	0.026	0.01	0.16
Carcass wt, kg	87.7	89.2	88.7	89.4	89.1	88.7	0.67	0.19	0.05
Backfat, mm	19.9	20.5	20.2	19.8	20.4	20.3	0.36	0.68	0.92
Loin depth, mm	64.6	63.9	63.3	63.7	63.8	63.3	0.67	0.11	0.45
Lean, %	60.2	60.0	60.1	60.2	60.0	60.0	0.21	0.56	0.94
Index	1.111	1.106	1.108	1.111	1.107	1.107	0.0040	0.55	0.96

^{a,b,c,d} Means with different superscript letter differ (P < 0.05).

Additional Considerations

As DDGS is a relatively new ingredient we are rapidly learning about sourcing and handling it. Disruptions to supply have been a concern with DDGS sourced from the US as rail companies get setup to handle larger quantities of this product. Due to the high fat content of the corn DDGS and fineness of grind flow ability problems of the DDGS and feed containing high inclusion levels have been a concern from feed bins and in feeders. Modifications may be required in storage and delivery systems to be able to handle the product. Due to the higher fiber content of the DDGS compared with corn and soybean meal, for each 10% DDGS that that is included in the diet, the volume of the diet will increase by approximately 3% compared with a corn soybean meal diet. The fat in corn DDGS has a relatively high concentration of unsaturated fatty acids, which may cause increased belly softness of pigs fed diets containing DDGS at higher inclusion levels > 20% (Whitney et al., 2006). However, this may not be a concern with all packers.

Screening for mycotoxins in corn used for ethanol and corn DDGS produced varies from frequent to minimal testing. It is very important that you determine the level of testing being done where your DDGS source is coming from as mycotoxins present in corn will be elevated 3 times in corn DDGS. As corn DDGS contains 9-12% fat and when replacing corn and soybean meal (4 and 3% fat) in the diet the total fat content of the diet increases 1.5-2% when included at 20-30% of the diet. Practical experience from feed mills suggests that pellet durability index (PDI) will be negatively effected with increasing levels of corn DDGS in the diet. However, there is a lack of research data to back up these experiences.

CLOSING COMMENTS

With the continued expected growth of the ethanol industry in North America and the resulting availability of corn and wheat DDGS there will be increased availability for and use of DDGS in swine diets. However, considering the variation in nutrient content it is extremely important you get informed as much as possible about the source of DDGS to be purchased or being used as all sources are not equal. It is recommended that proper quality control guidelines (minimum specification, nutrient analysis, mycotoxins screening, etc) be put in place and be conducted on a regular basis to allow diets be adjusted as needed to avoid risking animal performance.

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CANADIAN EXPERIENCE WITH FEEDING DDGS

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INTRODUCTION

Distillers Dried Grains with Solubles (DDGS) is a primary co-product of ethanol production from dry milling of cereal grains. Developing new markets for this co-product is essential for the ethanol industry's profitability and sustainability. However, livestock producers are being affected by increased ethanol production, as prices for feed grains are increasing, impacting cost of production. The burden on livestock producers may be decreased as DDGS can be used as both an energy and protein source in livestock rations. Since DDGS production in Ontario is expected to reach 1.5 million tonnes and a massive expansion in the U.S. continues, large quantities of DDGS will be available for livestock feeding.

In the United States approximately 15 percent of the DDGS produced is incorporated into swine diets. In contrast, very little is utilized by the swine industry in Ontario. Therefore research at Ridgetown College – University of Guelph, using Chatham DDGS (GreenField Ethanol), was undertaken to investigate the suitability of this protein and energy source for swine diets in Ontario.

PROJECT OBJECTIVES

The project evaluated the effects of feeding dried distillers grains with solubles (DDGS) to pigs based on measurements of growth, feed intake, economic returns and carcass quality. The following objectives were specifically addressed:

- a) To determine the effects of feeding DDGS (GreenField Ethanol - Chatham plant) at 10 and 20 percent of the ration based on pig growth rate, feed intake and efficiency, and carcass quality.
- b) To determine the economic benefits of feeding DDGS from the Chatham plant in pig growing and finishing diets.

METHODS

Trial #1

After a three week adjustment period, ninety-six pigs (33.2 ± 5.8 kg) officially began the trial on July 13th, 2004. Each pen (3 barrows and 3 gilts) was randomly assigned to one of three grower diets until they averaged 70 kilograms (within pen) of body weight (BW). Pigs were

then fed an assigned “finisher” diet until they were marketed (≥ 110 kg BW) by pen. The following dietary treatments were fed:

- Grain corn, SBM and premix (Table 1). A grower diet (0.83 % lysine) was fed until the pigs were 70 kg (per pen) followed by a finisher diet (0.69 % lysine) until they were marketed.
- Similar diets and feeding strategy to control group. However a 10 percent inclusion rate of DDGS was added to replace some of the SBM as a protein source. To achieve similar levels of lysine an increased protein (CP) level was needed in the grower (19.1%) and finisher (16.8%) diets.
- Similar diets and feeding strategy to control group with 20 percent DDGS added. An increased protein level was again needed in the grower (20.5%) and finisher (18.2%) diets to achieve similar dietary lysine levels.

The pigs (pens) were fed *ad libitum* with a required feed refusal or weighback taken once weekly. Ultrasound measurements (backfat and loin eye depth) were taken at the beginning of the trial, five weeks later and before the pigs were marketed by pen. All pigs were slaughtered at one location where carcasses were weighed and graded.

Table 1. Composition of experimental diets fed during growing and finishing feeding periods, kg of ingredient per tonne.

Ingredients	Control Diet		10% DDGS Diet		20% DDGS Diet	
	Grower	Finisher	Grower	Finisher	Grower	Finisher
Corn Grain (kg)	719	784	634	698	548	612
SBM (48%)	254	194	239	180	225	166
DDGS	-	-	100	100	200	200
RCAT Vitamin – Mineral Premix	27	22	27	22	27	22

Trial #2

Ninety-six pigs (48.8 ± 5.2 kg) were again randomly assigned to a pen and grower diet until 70 kilograms BW. They were then fed an assigned finisher diet until market weight (≥ 110 kg BW) with similar methodologies (trial 1) and data collected. The following dietary treatments were formulated and fed:

- Grain corn, SBM (control diets) and premix. A grower diet [17% CP (0.8% lysine)] was fed until the pigs were 70 kg BW followed by a finisher diet [14% CP (0.6% lysine)] until they were marketed.
- Similar diets and feeding strategy to control group. However a 10 percent inclusion level of DDGS + additional crystalline lysine was added to produce diets with similar lysine content.
- Similar diets and feeding strategy to control group. However a 20 percent inclusion level of DDGS + crystalline lysine was added to produce diets with similar lysine content.

- d. Crude protein levels were similar to control diets. However a 10% inclusion level of DDGS was added with no additional lysine supplementation. Dietary lysine levels were therefore significantly reduced [0.7% (grower diet) & 0.5% (finisher diet)].

RESULTS FROM EXPERIMENT #1

All growth, feed intake, cost and carcass measurements (Table 2) were not influenced by DDGS inclusion level (0, 10 or 20% of diet). Days to market, daily gain, feed intake and feed efficiency (F/G) estimates were similar for each dietary treatment.

Feed costs (grower & finisher diets) were determined for years 2003 and 2004 by taking ingredient inclusion rates and multiplying by an appropriate corn grain (Chatham + \$20 per tonne), soybean meal (Hamilton + \$20 per tonne) and DDGS price (Chatham + \$20 per tonne). A constant vitamin-mineral premix charge (\$600 per tonne) was also included in each cost estimate. Costs of gain were then determined for each DDGS inclusion level by year. Since daily gain, feed intake and feed costs per tonne were similar, costs of gain were also comparable ($P > 0.05$) for each dietary treatment.

Table 2. Effects of dietary treatment on pig growth rate, feed intake and cost, and carcass quality.

	Control Diet	10% DDGS Diet	20% DDGS Diet
Growth Rate			
Number of pigs	30	36	30
Final Weight (kg)	113.3	114.0	113.6
Days to Market (by pen)	75.7	78.0	77.9
Average Daily Gain (kg)	1.06	1.04	1.04
Feed Intake & Efficiency			
Total Feed Intake (kg)	220.5	218.4	215.7
Average feed intake (kg/d)	2.9	2.8	2.8
Feed efficiency (F/G)	2.7	2.7	2.7
Gain cost (\$/kg) – 2003	0.60	0.60	0.59
Gain cost (\$/kg) – 2004	0.62	0.61	0.60
Carcass Measurements			
Hot Carcass weight (kg)	91.8	92.5	91.7
Yield Index (%)	60.4	60.0	60.3
Grade Fat (mm)	19.3	20.4	19.0
Muscle depth (mm)	61.7	62.8	62.1

*All LS means within row were similar ($P > 0.05$)

RESULTS FROM EXPERIMENT #2

Days to market (Table 3), daily gain, feed intake and feed efficiency (F/G) estimates were similar ($P>0.05$) for each dietary treatment. Similar daily gain and feed intakes were expected as control and diets containing crystalline lysine were balanced to a constant (first limiting amino acid) lysine level. Dietary differences for loin and fat depth, and feed cost (\$/kg gain) were also not present ($P>0.05$). Similar growth rate, feed intake and efficiency estimates were also observed by Wahlstrom et al. (1970), Spiehs et al. (1999), Cook et al. (2005), and DeDecker et al. (2005) when DDGS containing diets were compared to typical corn-soybean meal diets. Cook et al. (2005), DeDecker et al. (2005) and Xu et al. (2007) indicated that performance was not impaired when diet contained up to 30% DDGS. In contrast Whitney et al. (2006) reported a reduced ADG when DDGS was fed at either 20 or 30% of the diet despite similar levels of daily feed intake. As a result, feed to gain (F/G) was increased for the 30% DDGS group. Linneen et al. (2007) also observed a linear ADG and daily feed intake decline as DDGS inclusion level increased from 0 to 20 percent. Reasons for the variation in performance are difficult to quantify but may be due to source analytical differences in DDGS quality (deLange et al. 2007).

Table 3. Effects of dietary treatment on pig growth rate, feed intake and cost, and carcass quality.

	Control Diet	10% DDGS + Lysine	20% DDGS + Lysine	10% DDGS no Lysine
Growth Rate				
Number of pigs	24	21	23	16
Days to Market (by pen)	56.6	56.7	55.2	56.6
Average Daily Gain (kg)	1.13	1.12	1.14	1.09
Feed Intake & Efficiency				
Total Feed Intake (kg)	174.7	170.6	171.3	170.9
Average feed intake (kg/d)	3.1	3.0	3.1	3.0
Feed efficiency (F/G)	2.8	2.7	2.7	2.6
Cost of gain (\$/kg) – 2003	0.62	0.59	0.59	0.56
Cost of gain (\$/kg) - 2004	0.64	0.60	0.59	0.57
Carcass Measurements				
Dressing Percentage	79.6	79.8	79.4	79.5
Yield Index (%)	61.3	61.1	60.5	60.8
Grade Fat (mm)	17.1 ^a	17.8 ^{ab}	19.3 ^b	18.5 ^{ab}
Muscle depth (mm)	62.0	62.6	61.3	64.0

^a and ^b LS means within row that do not share a common superscript differ significantly ($p < 0.05$).

Cook et al. (2005) and Whitney et al. (2006) also reported similar back fat and carcass lean measurements to 30% DDGS while loin depth was reduced in the Whitney (2006) experiment. Our results (Tables 2 & 3) indicate similar ($P>0.05$) carcass measurements when diets contained 20% DDGS or less.

CONCLUSIONS

- When diets were balanced to a constant lysine level (growing and finishing phase) similar growth rate, feed intake and efficiency estimates were obtained when diets containing 0, 10 or 20 percent dried distillers grains and solubles (DDGS).
- Feed intakes were similar for each dietary treatment indicating that DDGS was a highly palatable feedstuff for the pigs during the growing and finishing phase (35 to 110 kg body weight).
- Carcass measurements were similar for each dietary treatment with comparable dressing percentage, lean yield index, loin depth and backfat thickness observed.
- Gain costs were similar for each DDGS inclusion level. However due to similar feed efficiencies, gain costs were strongly related to ingredient costs. Therefore producers are advised to incorporate DDGS when this co-product is favorably priced relative to corn and soybean meal.

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CANADIAN EXPERIENCE WITH FEEDING DDGS

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ABSTRACT

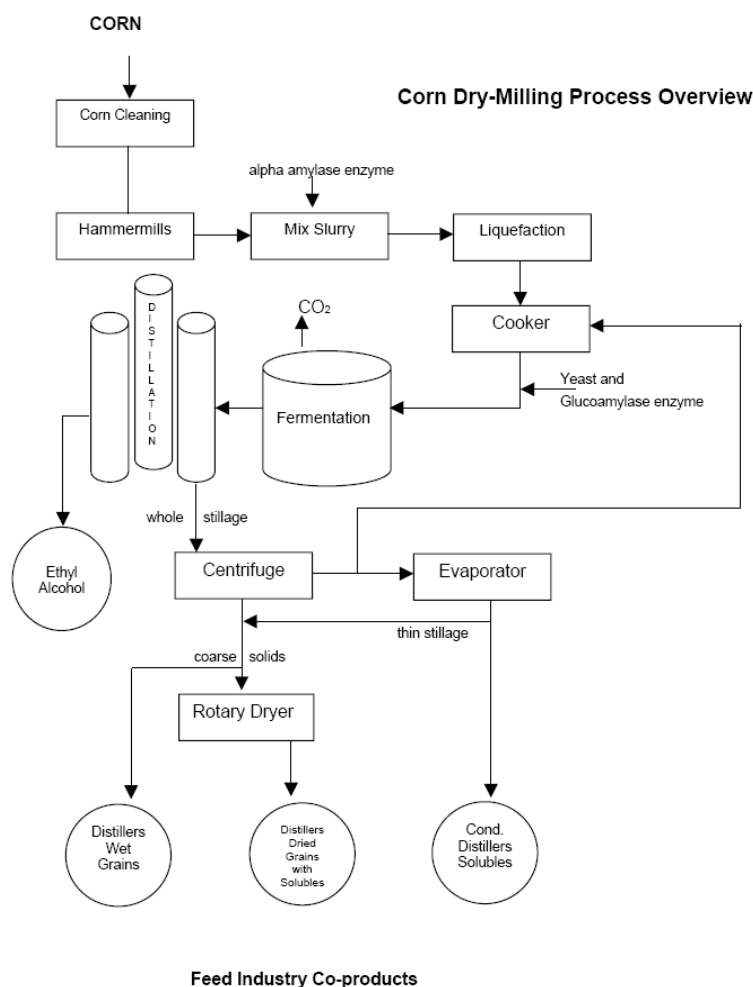
Corn Distillers Dried Grains with Soluble (CDDGS) is a byproduct of the ethanol industry. As commercial production of ethanol increases, the supply of corn distillers dried grains with solubles will increase. However, a number of risks must be addressed to efficiently utilize this feed ingredient in swine diets. Ingredient quality (energy, protein, amino acid availability, mycotoxin risk, etc.) must be monitored. Protein and fat content in batches of CDDGS can be highly variable between and within ethanol plants. The nutrient specifications used in the feed formulations need to reflect these changes in proximate analysis. Mycotoxins can be a risk depending on the mycotoxin content of the corn used in the ethanol facility. Beginning in the fall of 2006, the vomitoxin content of CDDGS was high (>8 ppm), which made it unacceptable for use in swine diets. Amino acid availability estimates of CDDGS showed a range in lysine availability from 64% to 84% which is consistent with estimates in the literature. Similar animal performance can be seen in GF pigs from 0 to 20% CDDGS in the diet provided that energy and amino acid levels are balanced. However, at higher dietary levels there is an increase in fat softness due to an increase in the polyunsaturated fat content of the carcass fat. In addition, there are production issues such as handling characteristics (flowability, bridging) and for pelleted diets, a decrease in mill throughput and increased fines can be seen when CDDGS exceeds 10% of the diet. Our experience has shown that CDDGS is a potential alternative ingredient for swine but a number of factors need to be addressed to use it properly.

INTRODUCTION

Corn Distillers Dried Grains with Soluble (CDDGS) is a byproduct of the ethanol industry. Government mandates have specified minimum levels of ethanol to be blended in gasoline. As cellulosic ethanol is not available in significant quantities, corn based ethanol production will be main source for the next several years. With the production of ethanol, corn distillers dried grains with soluble (CDDGS) is a co-product of the production process. As commercial production of ethanol increases, the supply of corn distillers dried grains with solubles will increase. The fermentation process removes the starch portion of the corn leaving a co-product with a higher protein, fat and fiber content. The technology used to produce ethanol has changed and continues to change. New technologies will change the type of ingredient that comes from the ethanol production facility. Part of the challenge facing the livestock feed industry is how to characterize the co-products coming from the ethanol industry. The future CDDGS “type” product will vary depending on the technology used in the ethanol industry.

We will need to re-think our definition of CDDGS, not so much as a single ingredient but as a group of ingredients.

GENERAL OVERVIEW OF ETHANOL PRODUCTION



In the production of ethanol, corn is cleaned of foreign material and then ground to a medium-coarse grind through a hammer mill. The corn is mixed with fresh and recycled water to form a slurry. The pH and temperature are adjusted and enzymes added to facilitate the breakdown of starch to dextrins or long chain sugars, in a process known as liquefaction. A second enzyme is added to take this down to simple sugars. A yeast, *Saccharomyces cerevisiae* is used to convert the simple sugars to ethanol and carbon dioxide. Fermentation is completed within 40 to 60 hours. The ethanol is then removed. The coarse solids are separated from the stillage. The thin stillage is recycled to the

beginning of the process or concentrated as distillers solubles which is then added back to the coarse solids and the mixture dried to form the co-product Corn Distillers Dried Grains. The water content of the solubles added may vary and require a longer drying time and higher temperatures. This step is one of the key determinants in quality of CDDGS for swine.

To increase the efficiency of ethanol production, newer systems are pre-fractionating corn, removing the hull and germ, increasing the starch content of the material that is fermented prior to fermentation. As an example, the company QTI (Quality Technology International) uses a wet milling process to remove the germ and bran. They have a higher protein, lower fat type distillers grain that is markedly different in nutrient profile than “standard” CDDGS. In assessing CDDGS quality, the key first step is to understand the process used in producing the CDDGS.

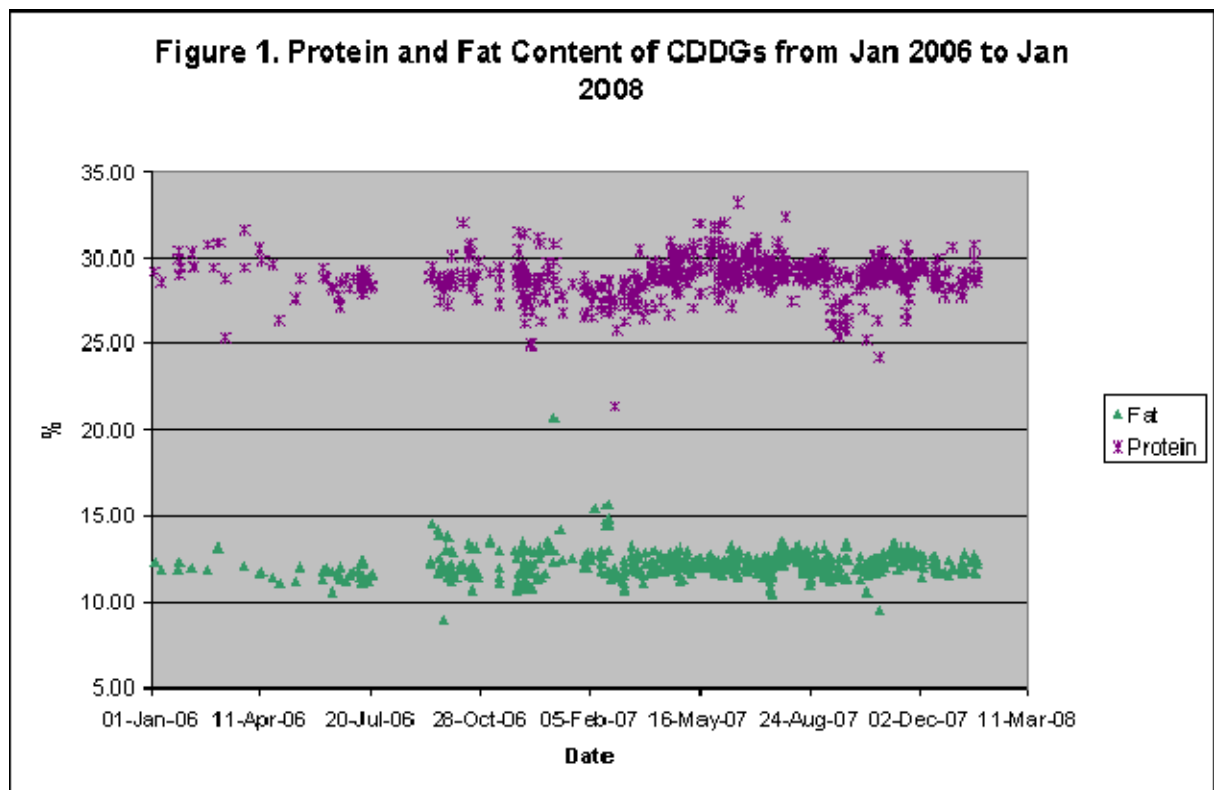
INGREDIENT QUALITY

The quality of Corn Distillers Dried Grains with Solubles depends on a number of factors. These are:

1. Corn quality – protein content, bushel weight, vomitoxin levels
2. Yeast used
3. Fermentation and distillation efficiency
4. Drying time and temperatures
5. Amount of solubles blended with dry material
6. Facility type – batch (modern) versus continuous (older)
7. Pre-fractionation prior to fermentation

Consistency in the process is the biggest driver in the variability in nutrient composition and availability.

The objective of a QA program is to assess quality of an ingredient that is to be used in the manufacture of a feed. When a co-product, such as CDDGS, is used the critical first step is to assess the quality of the material. This is more critical as the inclusion rate of the ingredient increases. CDDGS is a variable ingredient within and between ethanol plants (Figure 1).



Source: Nutreco Canada Agresearch

Utilizing constant energy and amino acid values for CDDGS would lead to inaccuracies in feed formulation. The use of a dynamic energy system allows a more accurate prediction of

the energy and nutrient content of CDDGS used in swine diets. This is especially true given the variability that one sees in CDDGS coming out of ethanol facilities. Predicting the energy content based on proximate analysis (dry matter, protein, fat, etc.) gives a truer prediction of the ingredient value of CDDGS. The older literature estimates of energy content are based on the CDDGS with lower fat contents and higher fibre levels. The CDDGS from newer ethanol plants have higher fat content and higher energy content than normally specified for CDDGS.

The protein content of CDDGS is high (>27%). However, like corn, the amino acid balance is poor, being low in lysine and tryptophan in comparison to other protein sources such as soybean meal. The other concern is the variability in amino acid availability. Like all heat-processed products, the drying process used can reduce lysine availability, decreasing the quantity of this essential amino acid actually available to the pig.

Hans Stein at the University of Illinois determined the availability of amino acids from several newer ethanol plants (Table 1). Of the 10 samples collected, lysine availability ranged from 44% to 63%. Other amino acids showed a lower range in availability. Drying temperatures can vary from batch to batch. The amount of syrup added back to the grains can vary altering the drying time and temperatures required. Under high temperatures, lysine in the protein can form complexes with sugars (called a Maillard or “Browning” reaction), from the syrup. These Maillard products reduce the availability of lysine in the CDDGS. This is a similar process that occurs in corn that has been subjected to high drying temperatures. Heat damaged product is normally but not exclusively, a darker colour.

Table 1. Crude protein and total and digestible lysine from 10 ethanol plants in the Mid-West U.S. (Stein et al., 2006).

Sample	DDGS Source										Ave	Std Dev	% CV
	1	2	3	4	5	6	7	8	9	10			
Crude Protein, %	27.6	28.0	27.2	29.0	26.7	24.6	26.6	28.4	29.1	27.3			
Total Lysine	0.82	0.85	0.78	0.76	0.68	0.74	0.82	0.71	0.88	0.83	0.79	0.06	8.15
Lysine, as a % of Protein	2.97	3.04	2.86	2.62	2.54	3.01	3.08	2.50	3.03	3.04	2.87	0.23	7.89
Digestibility Co-efficient	59.3	56.8	63.0	57	43.9	59.4	59.4	48.6	61.3	59.6	56.83	5.96	10.49
SID Lysine, %	0.49	0.48	0.49	0.43	0.30	0.44	0.44	0.35	0.54	0.49	0.45	0.07	16.54

The colour of CDDGS can be an indicator of amino acid availability, although the relationship between colour and amino acid availability is not definite. Colour is dependent on the processing parameters of the ethanol plant with darker colour product associated with poorer quality and indicative of heat damage. The colour of CDDGS should be in the gold to yellow colour. When one gets into darker colour material, the amino acid availability, particularly that of lysine can be reduced dramatically.

There are a number of analyses that have been investigated to improve on amino acid assessment of CDDGS. These are listed in Table 2. These assays have different degrees of correlation with lysine availability. One of the more promising assays is the Immobilized

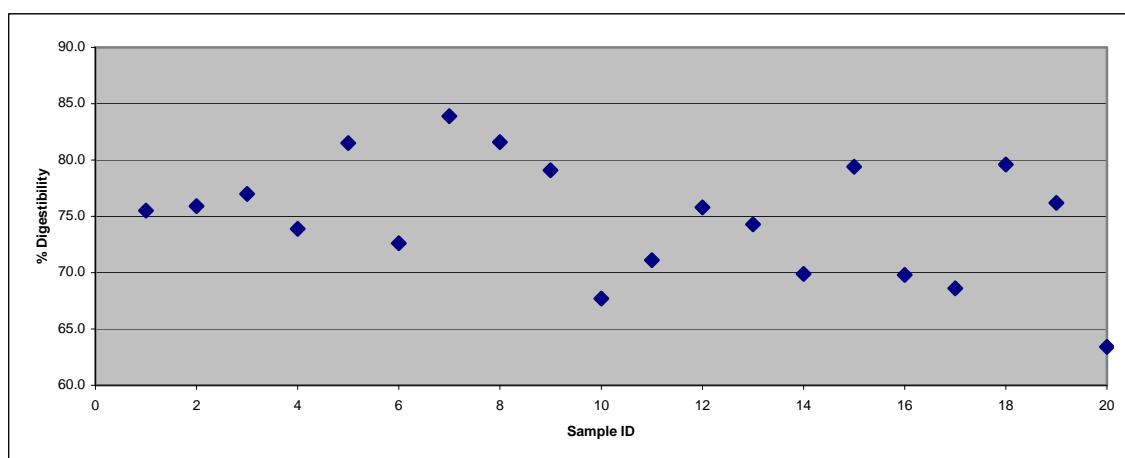
Digestive Enzyme Activity (IDEA) kit from Novus International. It relies on a direct measurement of amino acid availability and has a strong correlation with poultry amino acid digestibility estimates (Figure 2).

Table 2. List of methods and correlation to swine lysine digestibility estimate.

-
1. One-Step pepsin digest – $R^2 = 0.52$
 2. Two-Step pepsin-pancreatin digest – $R^2 = 0.79$
 3. Color – $R^2 = 0.53$ - 0.67
 4. KOH Solubility – $R^2 = 0.47$
 5. Furosine – $R^2 = 0.71$
 6. Reactive lysine – $R^2 = 0.66$
 7. IDEA Value– $R^2 = 0.88$ (Novus) vs. True Lys Dig. (Poultry)
-

Source: Stein et al., 2005

Figure 2. Estimates of CDDGS lysine availability using IDEA kits from samples collected from across Canada.



Source: Nutreco Canada Agresearch

One of the major risk factors in using CDDGS is the presence of mycotoxins. Mycotoxin levels will be proportional to the level of mycotoxin in the corn used. The removal of starch through the fermentation process concentrates the remaining nutrients by a factor of 3. The level of vomitoxin in the CDDGS will reflect the corn used in the production of ethanol, increasing approximately threefold. In the 2006 corn crop, vomitoxin was a major concern in the crop. As the 2006 corn crop was used in the production of ethanol, the level of vomitoxin in CDDGS increased concurrently. Based on the risk of vomitoxin coming from CDDGS, the ingredient was excluded from swine diets. The 2007 corn crop was clean with low levels of vomitoxin in CDDGS and therefore greater opportunities to include CDDGS into swine diets. The Shur-Gain QC program requires monitoring of mycotoxin levels in CDDGS, ensuring that total mycotoxin levels are minimized in the diet.

ANIMAL PERFORMANCE AND CARCASS/MEAT QUALITY

When diets are properly balanced, CDDGS can be included up to 20% in grower-finisher diets with no significant difference in animal performance (Table 3). There was a significant decrease in cost per kg of gain. However, the cost savings is dependent on the relative costs of corn, SBM, fat and CDDGS. The decision whether CDDGS is a cost effect alternative should be done in consultation with a nutritionist.

Table 3. Swine grower-finisher performance in response to graded levels of corn distillers dried grains in diets of pigs fed from 25 to 115 kg.

Treatment	DDGS, %			Sign. DDGS
	0-0-0	5-10-10	10-20-20	
ADFI, kg/d	2.342a	2.293ab	2.230b	0.010
ADG, g/d	864	855	848	
Feed:Gain, g/g	2.71	2.68	2.63	
Cost/kg gain, \$/kg	0.722a	0.706ab	0.683b	0.007
Feed Cost/pig, \$	64.88a	63.51ab	61.93b	0.047

Source: Nutreco Canada Agresearch

Provided that the amino acid:energy levels are kept in balance, there was no effect of CDDGS on carcass characteristics. However, there was some alteration in meat quality as fat firmness showed a trend to lower firmness scores with increasing CDDGS. Other meat quality parameters were not significantly affected. The concern with CDDGS is the high content of polyunsaturated fat. The fatty acid profile of pork and backfat is reflective of the fatty acid composition of the diet. The high proportion of polyunsaturated fat can contribute to soft carcass fat. When CDDGS exceeds 10% of the diet, there is a tendency to have softer fat in the carcass (Table 4).

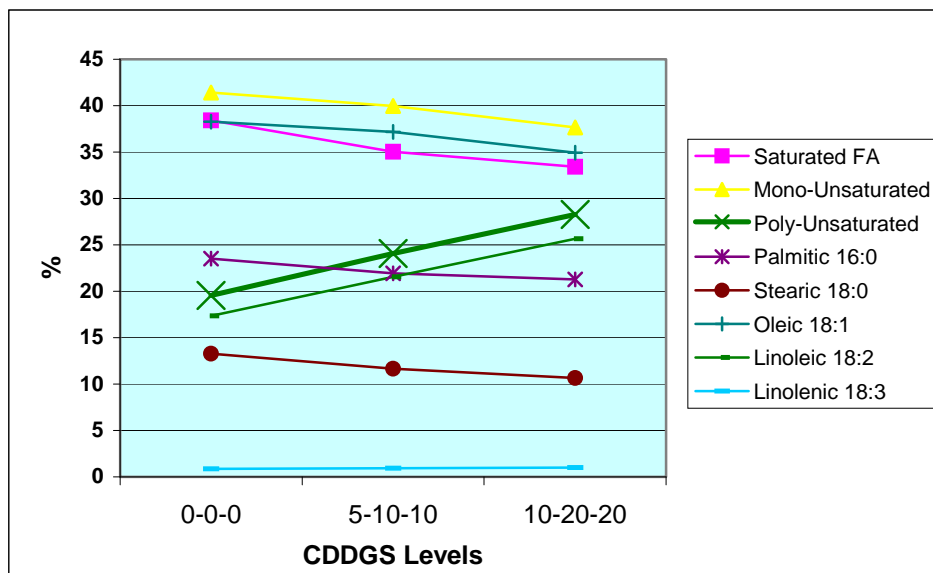
Increasing the level of CDDGS in the grow-finish diets elevated the level of linoleic acid and other polyunsaturated fatty acids by 45% compared to control diets (Figure 3). Similarly, the level of saturated fatty acid decreased in response to level of dietary CDDGS. The approach to reduce this would be to keep CDDGS to 10% or less in the finisher diets. With the higher polyunsaturated fat content, it may be advisable to increase the vitamin E content of the feed.

Table 4. Swine carcass characteristics in response to graded levels of corn distillers dried grains in diets of pigs fed from 25 to 115 kg.

Treatment	DDGS, %			P
	0-0-0	5-10-10	10-20-20	
Carcass weight, kg	89.09	89.06	89.78	
Backfat, mm	16.9	16.7	16.5	
Loin depth, mm	59.1	57.8	57.6	
Lean Yield, %	61.3	61.3	61.4	
Index	108	108	110	
Bending	2.1	1.9	1.8	
Fat Firmness	2.6a	2.1b	1.8c	0.09
Loin Firmness	2.9	3.1	2.7	
Fat Color Japan	1.8	1.8	1.9	
Loin Colour Japan	2.3	2.7	2.1	
Texture	2.0	2.1	1.7	

Source: Nutreco Canada Agresearch

Figure 3. Change in backfat fatty acid profile in response to increasing levels of CDDGS in the diet.



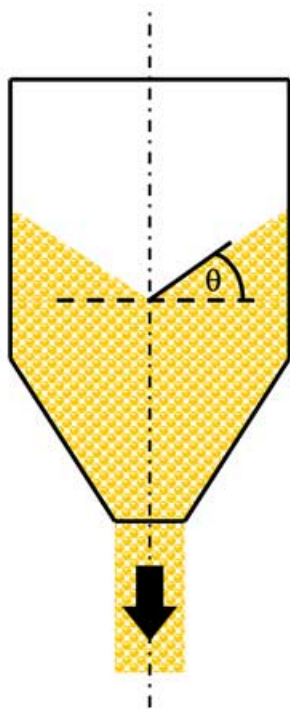
Source: Nutreco Canada Agresearch

PHYSICAL CHARACTERISTICS

Flowability

Flowability of CDDGS into and out of freight and storage facilities can be an issue given the nature of the product. The syrup portion has a high sugar content. The high sugar content can increase the stickiness of the product and reduce the flowability of the product. As the proportion of syrup added back to the CDDGS prior to drying increases, the stickiness or cohesiveness of the product increases, resulting in poorer flow characteristics. Flowability can be estimated by assessing the angle of repose. The Angle of Repose is the angle between a horizontal plane and the slope of a pile (at rest) formed by dropping from some elevation (Figure 4). The Angle of Repose is related to many of the flow properties of a material and is thus an indirect indication of flowability potential. Angle of Repose gives a reproducible numerical value for a given material, so it has been adopted as a standard measurement for general flowability behavior (Rosentrater, 2006). The optimum Angle of Repose falls within 25 to 35°. Materials having an Angle of Repose falling within that range are considered free flowing. Materials with higher Angles of Repose may have problems with bridging.

Figure 4. Equipment for measuring Angle of Repose. (Shurson, 2007)



A study by Rosentrater (2006) measured a range of physical characteristics of CDDGS from several methanol plants in the U.S. (Table 5). The study indicated a range of flowability estimates in CDDGS samples measured. The addition of anti-caking agents such as limestone to increase flowability has been used with limited success. In our experience in the feed mill with our equipment, flowability has not been an issue. However, this is a characteristic that needs to be monitored.

Table 5. Angle of Repose and other physical characteristics of CDDGS (Rosentrater, 2006).

Physical properties of typical DDGS (n=48)				
Physical property	Minimum	Maximum	Mean	Standard Deviation
Moisture Content (% d.b.)	13.21	15.01	14.37	0.42
Water Activity (-)	0.53	0.63	0.55	0.03
Bulk Density (kg/m ³)	389.28	496.40	479.97	28.29
Angle of Repose (°)	26.51	34.23	31.76	1.73
Color				
Hunter L (-)	39.99	49.82	43.05	1.96
Hunter a (-)	8.00	9.81	8.76	0.42
Hunter b (-)	18.22	23.50	19.44	1.14

Other Manufacturing Issues

There can be a variation in ingredient particle size which can negatively affect pellet quality. In addition, the “stickiness” of the ingredient, resulting from its hygroscopic characteristics, can cause some issues with balls of material during mixing. Adjustments to conditioning time and temperature will have to be made as increasing levels of CDDGS are included in the diet. Obviously, using CDDGS in mash diets alleviates some of these problems but not all.

CONCLUSIONS

As ethanol production from corn increases, the supply of CDDGS will increase. CDDGS can be used but a continuous assessment of the ingredient quality must be performed. Factors such as nutrient content (energy, protein, available amino acids, etc.), impact on carcass and meat quality, and mycotoxins must be considered when CDDGS are offered into swine diets to mitigate against the risk to overall animal performance and final pork quality when formulating with CDDGS.

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FIRE DISASTER RECOVERY: PRODUCER AND VETERINARY PERSPECTIVES

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SUMMARY

A barn fire destroyed the farrowing barns in a large farrow-part finish operation. Daily events are reported and actions taken and measures to mitigate future losses described. The swine industry needs some basic, flexible protocols to deal with disasters.

INTRODUCTION

We never think it could happen to us and we assume insurance will take care of it if it does. Disasters occur but we are never ready. Each one is different, be it fire, flood, tornado or hurricane. Different sections of the barn could be affected, each with their own ramifications if they get wiped out. You cannot predict how an emergency situation will unfold.

Other industries have post-disaster priorities that could be used as model for swine operations. For example during the 2007 wildfires in Southern California, the IT industry was concerned about balancing the preservation of an information infrastructure while considering the personal and professional needs of displaced workers. A reverse 911 system where residents and personnel in the field are notified of emergencies by email and phone calls was particularly useful. This may be preferred as people did not have time to log onto their corporate websites or voice mail. In addition, crisis task forces consisting of heads of various departments in a company were assembled. These consisted of managers from IT, operations, HR, finance and legal.

In contrast, in swine production the welfare of animals and people are paramount. Animals need constant care with a daily source of feed and water. Depending on the time of year, the environment can be a critical factor in animal well-being (winter vs. summer disasters).

This presentation reports the effect of a fire on well-isolated 1800 sow farrow to part finish operation. There were seven staff working in the barns. The buildings were constructed in different stages between 1982 and 2004. The dry sow barns (consisting of pens and stalls) was naturally ventilated with the remainder of the facility being power ventilated.

Producer comments will be shown in italics.

Monday August 20/07 (Day 1)

At 12:45 a.m. on the morning of August 20/07, a fire broke out. This fire would destroy all of the farrowing facility as well as the nursery, breeding and parts of the gestation barn. Phone calls were made to the staff who came in at 3-4 a.m. to help out.

I received an email sent at 4 a.m. from the owner:

Hi

Wow...is all i can say..how do u think that the universe is all giving to what u need???? tonight i heard the fire sirens at 12:45ami came out to see my entire pig barn completely engulfed in fire....all my pigs in these front barns are dead.....i sit here and ask why.....how.....who.....and what reason.....is there one.....i am trying to belive that it is a bad nightmare and i am waking up now and all my pigs are fine.... i don't know what to say....i am at a loss.....what is the lessons what is the reasons.....

The office area was also destroyed. No water or electricity service was available. Only a day's worth of feed was present in the overhead feed canisters of the drop system.

There were several burned sows that survived the fire but the captive bolt gun was destroyed. Euthanasia of these animals was required and neighbours had to destroy about 20 of these.

The Fire Marshal's office, police and insurance company all wanted answers. Other people and equipment needed to be mobilized. Debris had to be cleared so animals could be rescued. A hi-hoe with a grasping "thumb bucket" had to be hired for removal of much of the debris. Some animals were trapped and had to be freed and also pockets of burning material had to be exposed and extinguished.

Unfortunately, an emergency contact list for OMAFRA personnel was not readily available because the office was destroyed. Priorities had to be quickly established to ensure the ongoing safety of people and animals and the environment.

1. People

- a. Emergency personnel were on site initially (fire, police) to extinguish the fire and investigate the origin of the blaze. Fortunately there were no human injuries as a direct result of the fire. A listing of chemicals stored on the farm had to be provided to the fire department.
- b. Equipment operators (hi-hoe, back hoe, skid-steer, dump truck, livestock trucks)
- c. Barn staff were on hand to attend to animals if possible and accessible.
- d. Veterinarian, OMAFRA welfare staff, Ontario Pork, Ministry of Environment, engineer were needed.
- e. Hydro One had to cut off power. (Electricians needed to install new lines and panel boxes to serve the dry sow barn).
- f. OFAC needed to be contacted to deal with the media.

2. Animals

- a. If any survivors could be moved to one of the other barns for feeding and holding pending a decision on their health. Feed carts had to be assembled since there was no power for the remaining intact feed system.
- b. Animals that could not find spaces for were shipped. Since the load-outs were destroyed, a makeshift chute consisting of barriers and people were used to guide the animals. There were about 80 sows from the front barn adjacent to the burned area that were shipped later that day but 20 died in transport. Also, 70/400 gilts survived the fire but 5/70 of these died in transport. (Originally, it was thought that all of the gilts perished, but it was still too hot later that day with fires still burning to fully assess the survivors). The question arose as to when should animals be shipped after a blaze or can they be shipped if there is any danger of inhalation of toxic fumes and smoke. Waiting 2 days before making marketing decisions if possible is suggested.
- c. A decision had to be made what to do with animals approaching their due dates as there was no farrowing facility.

3. Environment

- a. Disposal of casualties had to be arranged, trying to respect the “48 hour” rule for disposal if possible. A permit was required for mass burial but took 3 days to acquire as the site required inspection to avoid leeching and run-off. Again, a hi-hoe with a “thumb bucket” to grasp the carcasses with an experienced operator was important to have. (It took 7 days to clean up the deads. Staff were becoming overcome from the work, sight and smells).

There were no coveralls and boots for personnel initially and these had to be replaced. It was August, hot and humid with danger of heat exhaustion and stress overcoming both animal and human. Gutters were flooded with water and plugged with glass and insulation.

Scheduled feed deliveries had to be cancelled. The SEW customer also had to be notified that no pigs would be available.

There was an amazing out-pouring of support from the community and beyond. The local Great Lakes New Holland dealer (Ken Monteith) made a Pay-Loader available for scraping up debris and also a tracked skid-steer for going up and down the alleyways and smaller pits. Also, Stan's Total Tire was out to repair flats caused by nails and rods. Tim Horton's provided coffee urns and friends brought donuts. The herd veterinarian provided additional large Styrofoam coolers and extra ice packs (used for vaccine shipments) to keep food and drinks cold. The farm family prepared food and served sandwiches daily to all present.

August 21/07 (Day 2)

Now 24 hours without sleep. As time progressed, it became apparent that the staff was traumatized and some other equipment and comforts were needed. These included:

- *all meals were cooked and water and snacks were served*
- *ice packs in coolers with cold drinks*

- *an eating area was set up in the drive shed, out of the sun*
- *frequent rest breaks*
- *portable toilets were set up as well as washing facilities*
- *masks, shoulder length rubber gloves (Longos Kitchen Supply), boots, coveralls and possibly hard hats*
- *a dumpster was secured for debris and trailers were brought in for scrap steel*

Fortunately, phone calls to the barn were forwarded to the owner's cell phone before the fire, so a mobile office was already in effect. (For 30 days after the fire, 720 calls were answered).

Long days were required, starting at 6 a.m. ending at dark (8:30 p.m.).

The insurance company required inventory records. Fortunately, computerized records were backed up online weekly to orbit.com.

August 22/07 (Day 3)

This was the start of meetings with external people. Salvage of material was organized. Zubik's provided trailers for scrap metal. Concrete was to be crushed instead of buried and could be used for future roadway material. (The insurance company originally wanted the deadstock to go to landfill and the rubble buried. There were also discussions on what constituted income loss, i.e. just the farrowing and/or due to farrow). The accountant was to meet with the owner and insurance company, with the owner becoming overwhelmed.

August 23/07 (Day 4)

Another meeting on farm with Ontario Pork representatives (Ron Douglas and Doug Richards), OMAFRA Welfare (Mike Draper and Penny Lawlis) and herd veterinarian Dr. Paul Morris to establish and maintain animal welfare parameters and come up with solutions to pending farrowings and a game plan to address the reality that the herd will need to be liquidated. Efforts were to be made to salvage as many litters as possible.

There was no time, energy or resources to build new farrowing facilities using used farrowing crates. Labor was stretched too thin as it was. A plan was established where sows would be moved around to take advantage of both stalls and pens for housing sows. A total of 272 sows were shipped over the next few days to make room. Every other stall would house a nursing sow and piglets would be allowed to come in. The fronts and backs of the stalls would need to be boarded to prevent escapes. Slats in the "creep" area would need to be covered to prevent piglets getting their legs caught and so oral iron could be administered. Heat lamps would need to be wired in. Cordless power tools were essential as no power was established yet in the barn.

A second fire broke out in some old sandwich wall at the end of the day when most had gone home. The hi-hoe had to be called back and return again in 4 hours to make sure the fire was out.

All sows due to farrow after mid-October were to be shipped as soon as possible. This amounted to animals upto and including mid-gestation at about 2 months. Regulations state that animals are not to be shipped if there is danger of farrowing during transport. The attempt here was to salvage as many litters as possible but recognizing that cold weather was on its way. We set the last weaning to be the week of Thanksgiving October 8, as cold weather follows shortly. (In effect the last farrowing occurred October 22).

In retrospect, we should have shipped the first 3 months of gestation. We had 8 weeks of farrowings with about 50% PWM as weaning age was brought down to about 14 days as only 136 stalls were available compared to the original 252 crates lost in the farrowing rooms. Dollars were lost on feed, cull sows, labor and mortality.

August 24/07 (Day 5)

Shipping was coordinated so feed tanks could be emptied. The feed system was in discrete bins and loops separate from other portions of the barns that had not been destroyed.

Another veterinary visit was made to help document welfare and recommend modifications. With the number of visitors, it was now becoming a public facility with a lot of scrutiny.

August 25/07 (Day 6)

More sows were shipped and clean-up proceeding. Priorities continued to involve removal of deadstock.

Made use of a Koolmees dump trailer (www.koolmees.ca) suggested and located by Walter Gross, Husky dealer in the area. This sealed trailer is pulled behind a tractor and hold liquids, body parts and liquid manure for dumping. It is manufactured in Norwich Ontario.

August 26/07 (Day 7)

No visitors, a quiet Sunday. The police are still cruising the road at random times.

August 27/07 (Day 8)

The hi-hoe is still working at clean-up.

August 28/07 (Day 9)

Another veterinary visit, more pictures taken to document welfare. *Shipped the herd boar "Gus".*

At times it felt like there were individuals attempting to poach staff away, equipment that survived the fire seems to have disappeared, especially cordless tools. Unknown if others burned or disappeared. Storage of parts, tools and equipment were in disarray.

September and October/07

Separation and recovery of steel, concrete and plastics, with the burning of wood proceeded. A machine recycles the concrete by crushing and removing the rebar making crushed gravel and sand for roadways.

The metal recycler complains of body parts adhering to the steel (somewhat like a roasting pan).

Meetings with builders, supplier accounts payable and other companies. The owner's job function became more of a project manager.

There were a lot of unknowns entering the fall, with no cash flow except from the culls to meet the payroll.

November 10/07

The last shipping (originally was to be Thanksgiving). With temperatures falling, growth slowed. Staff adjustments made with 2 quitting, 1 laid off and 2 remaining).

Most of staff injuries were bruising.

Certainly, the outcome would have been much worse if the fire had occurred in winter or if it was a wet summer. Animals could have froze or removal of debris hindered by snow and ice.

Recovery, Healing and Rebuilding

In spite of the fire and clean-up, a routine of getting up early and finding distractions and keeping busy continued. These included cleaning the house and doing renovations such as painting. It seemed that building or creating something would offset the destruction that occurred. It was a part of healing and recovery. Could not sit still and watch a movie for example. There became a great reliance on a network of positive people (not just in the family) who you could connect with and help you move forward.

The mutual insurance company (small) did not want to re-insure due to the high loss. The owner felt isolated. Other farmers who have had fires were contacted for their perspective in dealing with insurers.

The rest of the fall was spent emptying pits, washing the barns, disinfecting, eliminating rodents and determining measures to reduce risk of fire in the future. The use of an infrared heat gun to identify sources of heat is one technique. Consider using an outdoor furnace, no heat lamps, diesel power washer.

WHAT IF....

- The fire occurred in winter?
- The entire operation was power ventilated?
- The fire occurred on a Saturday evening?
- The barns were much further from an urban area?

IF IT HAPPENED AGAIN, I WOULD.....

- Ship sows up to 3 months gestation instead of shipping at mid-gestation
- *Consider buying a used hi-hoe since rentals can be expensive*
- *Keep up to date quotes (appraisals) on desired facilities*
 - *have replacement cost in the insurance policy only*
 - *anything greater than 10 years should have new replacement vs “like” replacement*
- *Be sure to get lots of rest*
- *Make sure morale is maintained, keeping everyone looking forward to homemade meals: the family took care of the family plus the employees*
- Maintain a call list for emergencies and keep in farm office and house:
 - OMAFRA personnel (Penny Lawlis and Mike Draper, 1-888-466-2372)
 - Ontario Pork (Doug Richards and Ron Douglas, 1-877-ONT-PORK)
 - Herd Veterinarian
 - Ministry of Environment (Glen Ross, Environmental Officer)
 - 1-800-268-6060
 - Hydro One (1-800-434-1235)
 - Contractor for hi-hoe and thumb bucket
 - Metal Recycler
 - Concrete crusher
 - OFAC (Crystal McKay, 1-905-821-3880)
 - Electrical Safety Association (Tony Titus) 1-877-372-7233 (www.esasafe.ca)
 - Electrician
 - Portable toilets
 - Local equipment dealers
- Have lots of cordless tools
- Have a list of chemicals stored on the farm
- *Make sure all farm data (inventory, production and financial) is stored off site, possibly scan documents so they are all digitized*

MECHANISM OF SMOKE INHALATION INJURY

In humans, smoke inhalation is the primary cause of death in about 60% to 80% of the 8,000 victims of burn injuries each year in the United States. Airway injury occurs in up to one third of those with major burns, and the risk of concurrent pulmonary damage is directly related to the extent of surface burns present. Inhalation injury greatly increases the incidence of

respiratory failure and acute respiratory distress syndrome. It is also the cause of most early deaths in burn victims. The mortality rate following smoke inhalation ranges from 45% to 78%. One study estimated that the burn-related death rate is 20% higher in people with combined inhalation injury and cutaneous burns than in those with cutaneous burns alone. (references cited by Lee-Chiong, 1999).

Lung damage occurs in two phases with the first phase characterized by the influx of cells and fluids and the release of inflammatory agents followed by repair and scarring.

The constituents of smoke can cause collapse of lung tissue resulting in fluid accumulation (edema) and burns in the neck area can result in upper airway scarring and reduction in airway diameter. Clearance of debris via the hair-like cilia is impaired and the risk of pneumonia is increased (Lee-Chiong, 1999).

Wood smoke is a very potent deactivator of surfactant, the material lining the air sacs (alveoli) that keeps them inflated. Loss of surfactant can result in the alveoli in areas of lung collapse to be adjacent to healthy areas of lung. The shear-stress of lung tissue movement with each breath causes further trauma to lung tissue with the release of inflammatory agents that cause further damage (Steinberg et al 2005). Therefore mortality can occur several days or longer following the insult (Sakano et al, 1993).

Carbon monoxide per se is not the primary origin of smoke inhalation injury (Shimazu et al, 1990). Multiple organ failure has been noted in dog studies (Nie et al, 2005). The mortality rate of human smoke inhalation victims without a burn is <10% but with a burn, the mortality rate is 30-50%, suggesting that thermal injury or its treatment is responsible for further lung damage (Clark, 1992). However, in burn patients, smoke inhalation resulting from a single domestic fire does not necessarily imply long-term respiratory health consequences (Bourbeau et al.1996).

Treatment

From a practical stand-point, provide fresh air as soon as possible. Try and humidify the air (try using a pressure washer for example). If animals are retained, there is a possibility of acute lung damage from the fire and smoke developing into pneumonia and airway disease days or weeks after the fire. This means that insurance adjusters will need to address post-fire claims. Anti-inflammatories are not effective in human victims.

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PULLING THE PIN ON DISEASE

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Having a new disease enter a herd is a risk that we all face in intensive swine farming. As units are becoming larger, a new (or new variant of) disease may have a greater financial impact, especially with tight (or nonexistent) margins.

Disease management may encompass everything from basic antibiotic therapy, a new vaccination program, flow management, partial depopulation or full depopulation.

A decision to choose a disease management option should focus on:

- What is the cost of the disease?
- What is the cost of treating this disease?
- How effective is the treatment?
- Are there risks associated with the treatment?

When we are determining the cost of the disease, we should be examining mortality rates and performance reduction. Performance indicators would include average daily gain, weight spread, and other expenses (feed, labour).

Table 1 indicates the approximate cost of disease.

Often, I hear that because a barn is continuous flow, that it is difficult to determine the daily gain or feed conversion. One method of getting around this is to determine the average weight in and weight out of a barn; number of pigs in the barn; determine a time frame (one to three months); and then look at premix or supplement purchases for that period. You can then figure back on how much feed was made and the weight of the pigs eating it. It's a rough calculation, but important to know and understand, especially with disease. With feed costs increasing, differences in F/G and ADG become even more important to monitor.

Direct costs of disease are always easy to figure out. These are drug costs (injectable, in-feed and water) and also the labour needed to administer the treatment. However, there are often other things that are applied along with drugs to reduce a disease's impact, namely changing the environment (warmer/colder); changing feed (mycotoxins to no mycotoxins) or changing how we manage the pigs (heavier weights going into a barn; reducing variability somehow). Once we start doing a number of changes at the same time as a treatment, it becomes difficult to evaluate that treatment. However, we still assign a cost to the drugs as given.

Table 1. Estimated effect of different diseases on ADG, FE, and cost of production.
(Source: Dufresne, L. 1999. Allan D. Leman Conference. pp 193-196.)

Disease	ADG	Feed Efficiency	Cost
Mange	4.5 to 12% 8% 0-5.7% 10%	10%	
Swine Dysentery	10-17%	3-10%	\$2.60-8.60/pig \$15/pig \$8.28/pig
Enzootic Pneumonia	3 to 7% 17%	3% 14%	
APP	8 to 17% 0-20% 34% 0-35%	3 to 10% 26%	
Atrophic Rhinitis	3 to 9 % 5-8% 0-13% -2.5-7%	3 to 6 %	
PRRS	10-20%		\$236/sow \$18.21/pig \$7.5 – 15/pig \$18/pig 6.90/17.25/sow m
Salmonellosis	7-44%	1-22%	

Risks can be associated with treatment. For example, a producer may elect to use serum injection as a treatment for PRRS. A sample of cull sows should be injected first to determine that the serum will not cause problems. Most of the time it doesn't. However, if this isn't done, there is a risk of causing more abortions and sickness in the herd, and therefore increased financial loss. We need to be aware of this before choosing this option.

Or, the vaccine may not be totally effective on its own. TGE vaccine is a good example. It is not as effective by itself in controlling TGE; however, when used in conjunction with feedback exposure and sow and gilt management, it becomes a very useful tool.

Some vaccines are spectacularly effective. The recent introduction of the circovirus vaccines are a great example. There is low risk with their usage, and the disease is considerably reduced, both in mortality and improvement in growth.

Return on investment is another way to look at investment in disease. A general rule is that a low cost/low risk intervention should return 20-25%. A high cost/high risk investment should return 150-300% on its use.

However, decisions should not be made on simple suggestions. A spreadsheet and sensitivity analysis (what happens if...) should be used when trying to evaluate what to do. Trying to do this on paper is not realistic anymore. There are many good programs available that will allow you to run several scenarios to determine what's best for your own operation.

Some diseases may be kept under control for the most part, but then may rear their ugly heads again and again to cause losses in the barn. APP is a good example of this, or having more than one strain of PRRS in a barn, or having APP, PRRS, Mycoplasma and throw in some E. coli and nasty Streps. The more usual case is trying to decide what to do in a barn with numerous problems.

At some point it's just not fun to go to the barn anymore. Disease has been creeping up. We tend to think that it's going to get better (to be human is to be optimistic). Some weeks are, many are not. Gradually, you realize that everything is sliding backwards. More pigs are getting composted.

WHAT TO DO?

First, get your barn examined. Call in your veterinarian, your feed representative, even your ventilation guy. Check everything out.

Then describe the problem. Is it disease? Is it something else? Is it a combination of events, a "perfect storm"?

If it is disease... What is it? How much of it is there? What is the cost of it?

WHAT IS THE COST OF CONTROL?

And ... get crunching some numbers. If there is a lot of disease challenge, you and your advisors may come up with a management plan – for now. Have an end point in mind if the challenges are serious. Monitor the effectiveness of the treatments.

And draw your line in the sand. When you reach the point that too many pigs aren't leaving the barn other than as a barbeque or as a compost pig, make the right decision.

Use the right tools. Spreadsheet analysis will easily let you plot many options, dependent on hog prices, feed inputs, and performance indicators. And you can monitor your line in the sand.

ON-FARM ANIMAL WELFARE AUDITS

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ABSTRACT

On-farm welfare audits may be carried out to assess compliance with legislative requirements, to monitor aspects of pig health and management affecting performance, or to provide market differentiation of product. Welfare is a multidimensional concept which may have different interpretations for different stakeholders, and the nature of the audit must reflect the purpose for which it is being carried out. Formalised audits to objectively assess aspects of pig production relevant to welfare under practical farm conditions have been most fully developed as part of Quality Assurance Schemes. Constraints on time and cost have resulted in such audits being largely based on evaluation of resource provision. However, interest in the possible application of animal-based auditing criteria has increased and such approaches are currently undergoing evaluation as part of a large scale EU research initiative.

THE NEED FOR ON-FARM ANIMAL WELFARE AUDITS

There are a number of reasons why animal welfare is an important subject for consideration by pig producers. Animal welfare is essentially a moral issue, and the importance attached to it therefore varies between individuals depending on their economic circumstances and the accepted ethical norms of their culture. However, in many European countries public opinion has pressured politicians into making adherence to animal welfare considerations a legal requirement. In 1991, the European Council published the first Directive setting out specific minimum standards for the welfare of pigs (Directive 91/630/EEC), which are legally binding on all member states. Several individual European countries have enacted even more demanding unilateral legislation on certain contentious issues (for example, the ban on sow stalls in the UK in 1991 legislation), and many of these initiatives are becoming more widely implemented as further Directive amendments (Directives 2001/88/EC and 2001/93/EC) increase community-wide legislation.

In most cases, the requirement to improve pig welfare is not counter to the interests of the producer, since it has been repeatedly demonstrated that poor welfare will result in reduced biological and economic output (Edwards et al., 2006). This is because of the many negative influences of the stress hormones elevated in conditions of poor welfare on the processes regulating health, growth, reproduction and meat quality. The particular aspect of welfare which has received greatest industry attention in this context is animal health, because of its clear and dramatic effects on profitability. Auditing schemes to identify and benchmark the prevalence of health problems on individual farms are consequently becoming more common

in the UK (for example, the British Pig Health Scheme, www.bpex.org/bphs; the National Animal Disease Information Service, www.nadis.org.uk).

However, a more powerful economic force affecting welfare auditing in the pig industry has been the growing trend for animal welfare to become a marketing issue in a number of European countries. Animal welfare is seen as a matter of great importance by EU citizens. A recent comprehensive EU survey (Eurobarometer, 2007) demonstrated that citizens ranked the importance of protecting welfare of farmed animals very highly (7.8 on a 1-10 scale). Although 79% of respondents felt that welfare needed to be improved, most of them (85%) felt that they knew little or nothing about farming practice. An important marketing message was that 72% believed that farmers should be financially compensated for higher costs linked to farming animals under more welfare friendly conditions, and 89% believed that similar standards should be applied to products imported from outside Europe. However, 54% felt it was not easy to find information on the welfare provenance when shopping, and this gives rise to the need for identifiable labeling of products according to objective and transparent criteria which relatively uninformed consumers can both relate to and trust. As pigmeat processing and retailing is carried out by fewer and larger organisations (dominated by the multinational retail chains), they have seen a need to demonstrate to consumers the ethical acceptability of the processes involved in production of the meat they sell. It was these considerations, which brought about the establishment of rigorous Quality Assurance (QA) Schemes, based on independent on-farm audits, which have now become a market requirement for the great majority of UK producers.

The measurement of animal welfare on-farm can therefore serve different purposes for different stakeholders. For government, it serves to verify adherence to legislative requirements defined by societal demands. For producers, it serves to monitor the conditions for animals that might be influential in production efficiency. For the marketing chain, it serves to inform and reassure consumers about the provenance of the food they purchase, and can thus be used as a component of marketing strategy to differentiate products.

THE DEFINITION OF ANIMAL WELFARE

The way in which animal welfare is measured for audit purposes is influenced by the perception of welfare of the stakeholders who must give credence to the outcome (Edwards, 2007). Three clearly different perspectives on welfare have been identified, focusing on natural living, biological function, and affective state (Fraser, 2003). The concept of natural living implies that animals should be raised in conditions akin to those inhabited by their wild ancestors or relatives. Whilst animal scientists often view such a perspective as subjective and poorly informed opinion, it is the major influence on consumer perception of welfare (Harper and Henson, 2001). As such, it has given rise to one type of welfare audit based solely on the nature of the production system and, more specifically, the use of extensive production systems with provision of outdoor access. For example, legally binding organic farming standards within the EU incorporate such criteria on welfare grounds (EC Regulation 1804/99). The definition of welfare in terms of biological functioning is much closer to the perspective of producers and veterinarians. It encompasses audits based on animal health and

other factors affecting level of production, and has become the basis of industry-derived welfare auditing schemes. The definition of welfare in terms of affective state (or feelings of the animal) makes it more difficult to evaluate in a practical way, and few audits currently address this aspect effectively. However, proponents of both natural living and biological functioning perspectives frequently believe that it will automatically be maximized by application of their criteria.

There have been many attempts to provide a scientific definition of animal welfare which will assist with objective discussion of its many complex issues and evaluation in different circumstances. The most widely used current definition within Europe is that based upon the 'Five Freedoms for Animal Welfare'. This approach was first formulated by the UK Farm Animal Welfare Council (www.fawc.org.uk), a body set up to advise the government on issues relating to farm animal welfare and to develop new standards for agricultural practice. The Five Freedoms are defined as:

- Freedom from hunger and thirst
- Freedom from thermal and physical discomfort
- Freedom from pain, injury and disease
- Freedom from fear and stress
- Freedom to express normal behaviour

The first three Freedoms relate to disciplines which have been extensively studied by animal scientists and veterinarians, where the needs of the animal are generally well understood and their fulfilment is necessary for both good welfare and good biological performance. This makes it relatively simple to derive auditable measures for on-farm assessment. The fourth Freedom, whilst more difficult to assess under farm conditions, likewise links both ethical and economic aims. However, greater difficulty is experienced in finding agreement on the interpretation of the fifth Freedom. Although for many in society it implies a 'return to nature', for scientists, it implies only a requirement to meet the 'behavioural needs' of the species within whatever farmed environment they are placed.

The actual measurement of animal welfare is fraught with difficulties, even under controlled scientific conditions. Whilst it is relatively straightforward to assess some aspects of physical welfare, since poor welfare results in characteristic changes in physiology and pathology of the body's regulatory systems, the ability to assess mental welfare is still at an early stage of scientific development. At a practical level, measurements of health, productivity, stress physiology, immunology, normal and abnormal behaviour have all been utilised in welfare assessment. However, many of these measures are not amenable to instant, on-farm evaluation because they are invasive or time consuming to make. Furthermore, the interpretation of these measures can sometimes be difficult, because they may show large differences between individual animals and yield conflicting evidence about a given set of circumstances. Farm audit schemes have therefore had to adopt many indirect approaches in carrying out practical welfare assessments on pig units.

PRACTICAL APPROACHES TO WELFARE MEASUREMENT

Two distinct approaches to on-farm welfare assessment can be identified. One uses direct measurements made on animals at the time of the inspection to give a “snapshot” of their level of welfare which is believed to be representative of that farm. These can be supplemented by information from farm records of health and performance over longer periods of time. The other approach adopts indirect measures of the extent to which the system under which the animals are kept should be adequate to provide for their needs, and therefore ensure that their welfare will be good. In practice, many auditing schemes use a combination of these “animal-based” and “resource-based” approaches, as shown in the following examples.

Freedom from Hunger and Thirst

Although knowledge exists on the precise nutrient needs of pigs of all classes, it is not practical to measure the feed intake of individual pigs or the composition of all diets in a routine audit. At a theoretical level the adequacy of feeds supplied can be evaluated by checking, through questionnaires or farm records, the conformity of diet specifications to nationally agreed nutritional standards, but this does not ensure correct practical implementation. However, the adverse effects of inappropriate nutrition are easily seen in the health and body condition of the animals – both the average level and the variability. Some audit schemes therefore define adequacy of feeding in terms of the end result: for example, sows must have a body condition score of at least 3 at farrowing and at least 2 at weaning (0-5 standard UK scale). Others set a minimum growth rate for finishing pigs, which can be checked in herd performance records. Whilst pregnant sows are restrict fed, and under-nutrition which compromises welfare may sometimes reduce feed cost without apparent performance deficit, growing pigs are generally fed ad libitum for maximum growth rate and deliberate underfeeding is unlikely. Inspecting every pig amongst hundreds (even thousands on larger units) is impractical and most audit schemes therefore focus on likely reasons for accidental feed or water deprivation of some individuals. Easily audited parameters are the number of feeding and drinking places provided to each group, and the flow rate of drinkers. These can be readily measured or counted in a random sample of pens and checked against criteria defined by the scheme as being adequate to ensure welfare.

Freedom from Thermal and Physical Discomfort

Extreme heat or cold stress is readily apparent from the lying behaviour of pigs, but in a short audit inspection when pigs are disturbed by entry of people into the building, this may not always be easily seen. Indirect assessment is therefore again most often favoured. Since good computer models exist to calculate the upper and lower critical temperatures of pigs at any stage of production, and in any housing system, the measurement of air temperature at pig level in a sample of pens can be checked against tabulated criteria for the acceptable temperature zone for those circumstances.

Physical discomfort is more difficult to assess, since it implies a knowledge of the feelings of the animal. However, some criteria which will have an influence on this have already been

legally defined; in particular the minimum space allowance to allow normal lying and locomotory behaviour. This can be checked by measurement of pen dimensions, both for total area and defined lying area, counting pigs and checking calculated space against tabulated audit criteria for the liveweight class and housing system. Extremes of physical discomfort can be measured indirectly through tissue damage caused by inappropriate flooring (for example, foot and leg lesions, bursitis, shoulder sores). However, since it is impossible to check all pigs, an indirect approach is again frequently adopted. Flooring parameters known to influence such damage can be measured (for example, slat and void dimensions) and checked against criteria defined by the scheme as being adequate for pigs of that weight class.

Freedom from Injury and Disease

The presence of serious disease is readily apparent on inspection, and most UK audit schemes now require quarterly veterinary inspection and reporting. Subclinical disease can be assessed by inspection of farm records of pharmaceutical usage, and the compliance with housing and management practices designed to minimise health problems can be checked. Thus, the presence of adequate isolation and hospital facilities, cleaning and disinfection procedures and skin cleanliness of stock can be verified. The incidence of injury arising from inappropriate pen design or construction material or, as discussed above, the components of pens likely to give rise to injury, can be scored in a sample of pens. However, many injuries result not from inadequate pen design but from problems of management resulting in fighting or vice (tail, ear and flank biting). Whilst the extent of such problems can be quantified through measuring skin lesion scores of a sample of pigs, it is more difficult to measure related indirect indices other than the resource provision for nutritional, thermal and physical comfort needs discussed above. Whilst facilitating good welfare, this approach does not guarantee freedom from such socially-derived welfare problems, since simple, easily-measurable parameters which reliably determine whether or not these multifactorial problems occur do not exist.

Freedom from Fear and Stress

Even greater auditing problems arise in the case of assessing welfare in terms of the fourth Freedom. Objective physiological measures (for example, measurement of heart rate characteristics or dynamic profiles of stress hormones such as plasma cortisol) are currently impractical in an on-farm audit situation. Whilst some of the parameters known to influence fear and stress (stockmanship and handling, social stability, environmental predictability) have been extensively studied, their correct implementation is difficult to assess in a short inspection visit. Indirect measurement of such parameters as skin lesions, space allowance, and adequacy of feeding and drinking facilities is relevant, but not comprehensive. Test measurement of approach response to humans, while scientifically validated as a sensitive measure of quality of stockmanship, is time consuming and difficult to implement, and has consequently not yet been adopted by current auditing schemes.

Freedom to Express Normal Behaviour

This is the most contentious area in terms of welfare assessment. Some consumers would wish to see certain production systems specified (for example, outdoor or straw bedded) and

others banned (for example, tethers/stalls, farrowing crates, fully slatted pens) according to their perceived compatibility with 'natural behaviour'. For scientists, however, this Freedom focuses on the identification and satisfaction of 'behavioural needs'. These are behaviours which an animal is strongly motivated to perform in a given set of circumstances, as a result of stimulating factors from its external environment and/or internal physiology. If such behaviours are prevented when these circumstances arise, the welfare of the animal is compromised and detrimental effects on physiology and/or behaviour can be seen. Under practical conditions, these can be measured as the incidence of vice (tail, ear and flank biting) or stereotyped behaviours (repetitive, invariant behaviours with no apparent function) such as bar biting or sham chewing. Growing understanding of the reasons underlying expression of such abnormal behaviours is starting to indicate appropriate preventive strategies, which can then be audited. For example, bar biting in the pregnant sow arises from the combination of hunger and absence of foraging substrate towards which to direct the appropriate behaviour triggered by this condition. In consequence, either nutritional changes aimed at reducing hunger or provision of foraging substrate such as straw can be an effective remedy. The importance of environmental enrichment to meet behavioural needs is widely recognised, and current EU legislation specifies that all pigs must have '... access to straw or other material or object suitable to satisfy those [behavioural] needs'. In both enforcement of legislation and in most QA schemes, however, the current interpretation of this is still somewhat vague, although whatever criteria are chosen can be readily audited.

DEVELOPMENT OF INDUSTRY-BASED WELFARE AUDIT SCHEMES

Prior to the 1990s, on-farm welfare audits for pig production were very uncommon. Compliance with legislation was monitored by government veterinarians only to the extent of identifying serious cruelty issues for prosecution, since Welfare Codes in force in the UK at that time had no obligatory legal status. Whilst comprising very detailed booklets of good practice, the Codes were, and still are, only recommendations. The few formalised schemes in existence at that time, such as "Organic" or "Conservation grade" production, which had defined production criteria for some welfare related aspects such as later weaning, increased space allowance, provision of bedding and outdoor access, encompassed only a very small part of pig production. Furthermore, the first QA Schemes set up by innovative retailers were relatively unsophisticated, defining welfare only according to generalised production methods (notably pigmeat produced in outdoor systems). These schemes achieved a price premium for a differentiated product and individual farms contracted into the scheme, agreed to produce pigs within the specified production system, and in return received a price premium for their animals.

Following this lead, the growth of industry-based QA Schemes began during the 1990s and was pioneered by the Scottish pig industry. By the mid 1980s this industry was in crisis as a result of major reductions in number of producers, national herd size and number of abattoirs. As a small industry in a region with low pigmeat consumption and far from the major UK centres of population, with a relatively high feed cost and poor production efficiency, the long term future looked grim. In assessing the options, it was apparent that this industry could never compete effectively on production cost alone. From this circumstance, was born the

concept of creating a differentiated product by establishing a national, producer-lead Quality Assurance scheme to create a product which would be in demand by retailers and consumers, providing both market security and a price premium. Thus the Scottish Pig Industry Initiative (SPII) developed what was claimed to be the world's first 'farm to shop' Quality Assurance scheme for pigmeat, encompassing farmers, abattoirs and retailers.

Within this scheme, animal welfare was only one of three key target components, designed to address the concerns expressed at that time by consumers, specifically relating to:

- Animal welfare – humane production methods
- Food safety – freedom from microbial contamination and antibiotic residues
- Product quality – consistently good eating quality

The starting point for the SPII scheme, and all subsequent QA schemes for livestock production, was a clearly specified code of production practice, with independent inspection of every farm to ensure that these codes were adhered to. Whilst the original SPII scheme required independent inspection at 6 monthly intervals, the cost of this was such that inspection frequency was subsequently reduced in this and most other schemes to one inspection per year, with interim quarterly reports being required from the farms own veterinarian.

In the original SPII scheme, the written production codes included a requirement for:

- adherence to all welfare legislation and government codes of practice
- documentation of veterinary input and health management programmes
- appropriate feed specifications and ingredients
- safe use and accurate recording of medicine use

Great emphasis was placed on the day-to-day housing, management and husbandry of the pigs. Thus the categories in the codes included:

- origin of stock
- management, stockmanship and welfare
- veterinary medicines and health supervision
- stock accommodation and handling facilities
- feeding and water provision
- farm cleanliness

The success of the Scottish scheme led to a proliferation of other schemes, both in the pigmeat and other livestock sectors, which sought to attract the same market advantages. Growth of the QA schemes was further promoted by the realisation of retailers that these could meet their legal requirement to demonstrate 'due diligence' in the marketing of safe food, as required by UK legislation under the 1990 Food Safety Act. At this point, QA scheme membership started to become a basic market requirement rather than a niche marketing opportunity. At the present time, three major schemes dominate the UK industry and have largely standardised their audit practices and requirements relating to animal welfare (Assured British Pigs, 2007; Genesis QA, 2007; SFQC, 2007).

SPECIALISED ANIMAL WELFARE QA SCHEMES

As the early industry-based schemes grew to encompass the majority of all UK pig production, and scheme membership became a market requirement but ceased to attract a significant price premium, they had to become increasingly pragmatic about the level of welfare requirements. Standards had to suit all systems, and auditing ensured no more than compliance with all existing legislation and application of high quality stockmanship and management in areas relating to production efficiency and product safety. In response, other specialist schemes based wholly around animal welfare were developed to meet a perceived ethical and market need. The most significant of these was the Freedom Food Scheme, established by the Royal Society for the Prevention of Cruelty to Animals (RSPCA), the largest and long established UK animal welfare charity. In promoting such a scheme, the RSPCA stated that, “The RSPCA has no other interests except those of the animals. The public (and the food industry) can trust in Freedom Food to be totally independent and to implement strict but practical welfare conditions consistently across the industry”.

The production standards for the Freedom Food scheme were drawn up by RSPCA technical specialists, in consultation with other animal welfare experts. They were based on the “Five Freedoms”, and specified a number of areas in which production practice was required to go beyond the basic requirements of welfare legislation. The standards for pigs and laying hens were first published in 1994, with standards for most other farm livestock species being developed subsequently and now in place. The auditing process is essentially the same as for the industry-based schemes. Adherence to standards is checked by trained assessors but, in addition, random and unannounced checks can be carried out at any time by officers of the RSPCA. Special requirements of the scheme (over and above existing industry schemes) include loose housing of all sows including lactating sows (initially implemented at a time before UK legislation made this a national requirement for dry sows), the provision of straw or other bedding to all pigs, higher space allowances, and a ban on all mutilations (castration, tail docking, teeth clipping, nose ringing) except under special circumstances of veterinary need (RSPCA, 2005). The standards are regularly updated as new welfare knowledge indicates it to be necessary.

THE EU WELFARE QUALITY PROJECT

Whilst welfare assessment has now become well established in Quality Assurance schemes, concerns are frequently expressed about the heavy dependence on resource-based measures, rather than the more direct evaluation of actual welfare outcomes through animal-based measures (FAWC, 2005). In a move to both try and reduce consumer confusion by creating a standard EU assessment scheme, and to make this scheme animal- rather than resource-based, a large EU research project was initiated in 2004 and is currently in progress. The Welfare Quality project is seeking to develop an overall welfare assessment system which is scientifically valid and widely accepted by stakeholders (Blokhuys et al., 2003). The project involves both social science research into the perspectives of different stakeholders (farmers, retailers and consumers) and animal science research into the development of valid animal-based measures. Recognising the multidimensional nature of welfare, a set of criteria around

which welfare assessment should be structured was designed (Botreau et al., 2007). It was considered important that measurements were exhaustive (containing every important viewpoint), minimal (containing only necessary and relevant criteria), that criteria were independent of each other, and agreed by stakeholders. Finally 12 sub-criteria, grouped into four main criteria, were agreed (Table 1).

Table 1. The criteria and subcriteria defined by the Welfare Quality project to develop an overall welfare assessment

Criteria	Subcriteria
Good feeding	1. Absence of prolonged hunger 2. Absence of prolonged thirst
Good housing	3. Comfort around resting 4. Thermal comfort 5. Ease of movement
Good health	6. Absence of injuries 7. Absence of disease 8. Absence of pain induced by management procedures
Appropriate behaviour	9. Expression of social behaviours 10. Expression of other behaviours 11. Good human-animal relationship 12. Absence of general fear

Measurements to assess each of these criteria were developed from a combination of literature review and experimentation. Each measure was required to meet strict criteria for:

- Validity – ability to measure the underlying welfare criterion
- Sensitivity and specificity – ability to detect true cases of welfare deficit and avoid false positives
- Reliability – ability to show good agreement over time and between observers
- Feasibility – ability to be carried out in the range of farm conditions within acceptable time and cost constraints

Following this research phase, a preliminary set of welfare measures for breeding pigs and growing pigs were agreed (Velarde et al., 2007 a, b). These are now being evaluated in pilot studies across a range of different production systems, whilst the best way to integrate the results from the different measures into an overall welfare categorization is also being formulated.

CONCLUSIONS

On-farm auditing of animal welfare has an important role to play in reassuring both the citizen and the consumer that livestock production operates in an ethically acceptable way. Increasing consumer awareness and concern about food production methods, and the market power of the major international food retailers, will ensure that welfare auditing continues to be a core requirement for pig farming in the UK, and will promote the spread of such approaches within Europe and worldwide. It also has a currently under-utilised role in good production practice, as a means of optimising performance through removal of constraints preventing animals from achieving their genetic potential. However, experience to date suggests that relatively few producers are likely to obtain a significant price premium through niche marketing of pigmeat from 'welfare friendly' production systems. Harmonisation of welfare standards and animal-based farm assessment protocols are a policy objective of EU politicians.

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DEVELOPING THE ANIMAL CARE ASSESSMENT

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INTRODUCTION

In 2005, the Canadian Pork Council launched the Animal Care Assessment, or ACA, an auditable on-farm program for animal care. The program follows in the footsteps of the on-farm food safety program, CQA®, which is now a core program in the Canadian hog industry.

Producers, already burdened with an increasing array of programs and requirements, voluntary and mandatory initiatives, may wonder why such a program is needed, and what value it will bring. This presentation will outline the pressures that led to the creation of the program, the steps and challenges faced in developing the initiative, and the current environment that makes having such a program critical.

PRESSURES TO DEVELOP AN ANIMAL CARE ASSESSMENT

The early indicators for the Canadian Pork Council to embark on the development of an animal care program were both domestic and international.

On the domestic front, the retail and foodservice sectors were asking, “What kind of care do hogs receive?” They started questioning the industry as consumers, in turn, were questioning them. The response from industry was, as it has been for some time, “Producers are taking good care of their animals. Recommended codes of practice are being followed. Trust us. It just makes sense that producers take care.”

But in this age, trust is not enough. The landscape has changed and both consumers and the farming community have changed with it. There is a gap between consumers, that are further and further distanced from the farming community, and the farm. Consumers expect animals to be given proper care and treatment and want evidence that this is being done.

It is providing this evidence that is challenging. To start, we simply do not know what production practices are being followed in terms of care of livestock. Recommended codes of practice are considered to be the industry norm, but there is currently no way to validate this. Other initiatives, such as food safety, have already moved to setting minimum requirements and ensuring these requirements are met through external reviews of both the records and the facilities through CQA®. And yet animal care has not.

On the international front, there has been a lot of activity. Certainly, Europe has faced extreme pressure from animal activist groups for quite some time. And these groups were very effective. Most of the Canadian hog industry is well aware of the pressures that began in the United Kingdom which led to a regulated outcome in 1992 to ban sow stalls by 1999. These pressures spread throughout Europe and the legislators made it their business to address animal care. By 2001, the European Union issued a directive outlining minimum standards for the protection of pigs, which included the phase out of sow stalls by January, 2013.

Animal activist groups in Europe also learned that while regulatory changes are useful, market pressures are often more timely and as such, focused actions on food retailers. This proved to be very successful as retailers were concerned about losing market share unless they took action. The result was a proliferation of private label programs, particularly in the U.K., with a focus on animal care.

When we examined what the U.S. was doing, the pressures were mounting. Again, animal activist groups were very much at the fore and this time, the focus was on the foodservice industry. McDonalds, Burger King and Wendy's all established an interest in animal care and setting requirements for their suppliers. Then in 2001, the Food Marketing Institute and the National Council of Chain Restaurants began to develop animal care requirements together. The National Pork Board did its part, as well, in recognizing the pressures on the industry and developed the Swine Welfare Assurance Program (SWAP). Launched in 2003, it was focused on producer education.

All the signals were that something needed to be done in Canada, otherwise, the agenda would be taken out of the hands of industry, and put into the hands of animal welfare and rights groups and legislators. The Canadian Pork Council brought together key animal care researchers, producers and governments to determine what should be done, and the seeds of the Animal Care Assessment were planted at the end of 2002 and early 2003. It was quickly determined that an auditable program with minimum animal care requirements was needed. The codes of practice were great, but they did not establish a bar, below which was unacceptable. This was needed.

CHALLENGES IN PROGRAM DEVELOPMENT

But the development of an animal care program was not simple. The Canadian Pork Council had a good deal of experience in developing the food safety program, which was a relatively straightforward process as the development followed the guidelines of HACCP - or Hazard Analysis Critical Control Points. HACCP was generally accepted worldwide as a solid approach to food safety, although moving it to a farm setting was something of a novelty.

But there was no HACCP for animal care, no set of generally accepted guidelines that could form the foundation for the development of a program. And while animal care programs existed in other countries, there was a wide variety of approaches to consider.

For program content, some programs focused on the design of the building and the animals' environment, others on the animals themselves. For program assessment, some programs used a set of questions to which producers needed only to score a certain level overall, others would use a weighting system that put more weight on some questions, and others still would use a set of minimum requirements that had to be met.

Behind all this is the question of what are the appropriate indicators of animal welfare? This, we learned, depends on the questions you ask, and the questions you ask depend on how you see things, your values, and your perspectives. Even in science, background values play a role in the type of research in which scientists choose to engage. What is the best approach? Should we be examining animal health and productivity as a good indicator of welfare? Is it more appropriate to look at whether the animal is in as close to its natural setting as possible - or at least able to perform the functions that it would if in its natural setting? Or, should we be providing animals with choices and let them determine what constitutes their best welfare? (Weary, National Farm Animal Care Conference, 2007)

All this to say that there are many complicating factors in developing an animal care assessment and as there is no one clear path, the outcome will not be satisfactory to all.

What did we do? The group developing the program loosely used the HACCP approach, that is, determined where things could go wrong on-farm that could impact animal welfare, and ensured that steps are in place to eliminate or minimize these. This philosophy led to a program that includes questions that are animal-based (looking at the animal, body scoring, examining for cuts or bruises), design-based (looking just at the environment in which the animals live, for example, space), and process-based (ensuring basic protocols are in place to address animal care issues, such as euthanasia and handling sick pigs).

We also determined that the program approach would set out minimum requirements that had to be met in order to be on the program, rather than using a weighting system or scoring approach.

In terms of the values, we each brought our own set to the table.

WHY THE PROGRAM IS CRITICAL

The focus is now on encouraging participation. And this is difficult with no concrete financial incentives being provided. What are the incentives, if not financial? The incentives are in what lies around us - the global situation, a situation that is changing and changing fast.

Europe continues to focus on animal care, with considerable resources at the government level allocated to animal care issues. There is a massive undertaking called the Community Action Plan for the Protection and Welfare of Animals (2006). The EU is undertaking initiatives in developing welfare indicators, consistent labeling approaches, consumer information and raising the level of awareness of animal care issues at the international level. (Cornelius Rhein, presentation to the National Farm Animal Care Conference, 2007).

Australia and New Zealand have both issued new codes of practice for pigs that include minimum standards with regulatory bases, and educational elements. Both include phasing out sow stalls.

In the United States, at the producer level, the National Pork Board re-released its animal care program in 2007 to be more closely linked with the very successful food safety program, PQA. The new PQA Plus includes animal care. What is even more striking is the action that has taken place at the legislative level, with the banning of sow stalls in Florida, Arizona, and Oregon. These actions are critically important. The Florida action in 2002 was widely viewed as a unique situation. But when animal activist groups promoted the proposition to ban sow stalls in Arizona in 2006 in a voter ballot, it was taken very seriously by the agriculture community, who aggressively opposed the action. And yet the proposition passed. And the Oregon decision to ban sow stalls in 2007 took place at the state legislature, without a voter ballot.

And of course, we must consider industry action, at both the foodservice and processor level. The decision by Smithfield foods in early 2007 to phase out sow stalls in company-owned facilities took many by surprise, (as did the follow-up announcement by Canada's Maple Leaf Food to do the same). There was a flurry of announcements around the same time by foodservice players regarding sow stalls by Wendy's, Burger King and Wolfgang Puck.

The actions in the United States in 2006 and 2007 taken by industry and government regarding animal care, and in particular, pig housing questions, are unprecedented in North America and a sign of things to come. Animal care issues are not going away, as the European Union will attest to. They are here and here to stay. At a multinational level, the international animal health organization, the OIE, is tackling animal care, and will soon be looking at developing on-farm guidelines.

In view of many of these activities, we cannot rule out animal care as a trade issue. Perhaps it will appear in trade agreements. But more importantly, it will most likely end up in marketing efforts, playing out on product labels, billboards and magazine ads. And the Canadian hog industry is very vulnerable to trade actions, with a heavy reliance on export markets for both live hogs and pork.

The current pressures are large and looming and should provide the incentive to participate in an animal care assessment initiative. It is the basis on which we can address animal care actions in Canada.

CONCLUSIONS

Developing a national, credible, animal care program was necessary given both the domestic and international pressures facing the industry. But building the program is not enough. Producers need to participate, and to participate, they need to see a benefit. While the incentives are not financial, they are still clear. Without such a program, without such a defense, to domestic and international customers and the public, there is little to stand on.

OPTIMUM SOLUTIONS FOR GROWER-FINISHER PIGS

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ABSTRACT

Dynamic integrated models, such as Watson[®], are available and being used to improve performance and profitability of finishing pigs by enhancing the decision-making process. One of the main purposes of an integrated management approach is to bring together the complex interactions between the animal, its environment and its diet, into a system that will accurately predict the animal's performance under commercial conditions. Applying this technology will predict 1) the cause-and-effect responses to changes in the production environment; 2) the subsequent financial implications of these changes; and therefore, 3) the optimum nutritional and/or financial strategy. It is important to note that optimum solutions are farm-specific and no one solution fits all because of the inherent differences in production characteristics on each farm (e.g health status, genetics, housing, ingredient/feed costs). The judicious use of these integrated management models can and does assist the producer make better decisions, in a constantly changing production environment, as well as assign financial consequences to the decision-making process. A number of different optimum strategies focusing on nutrition, feed management and marketing are presented as well as examples of their on-farm application.

INTRODUCTION

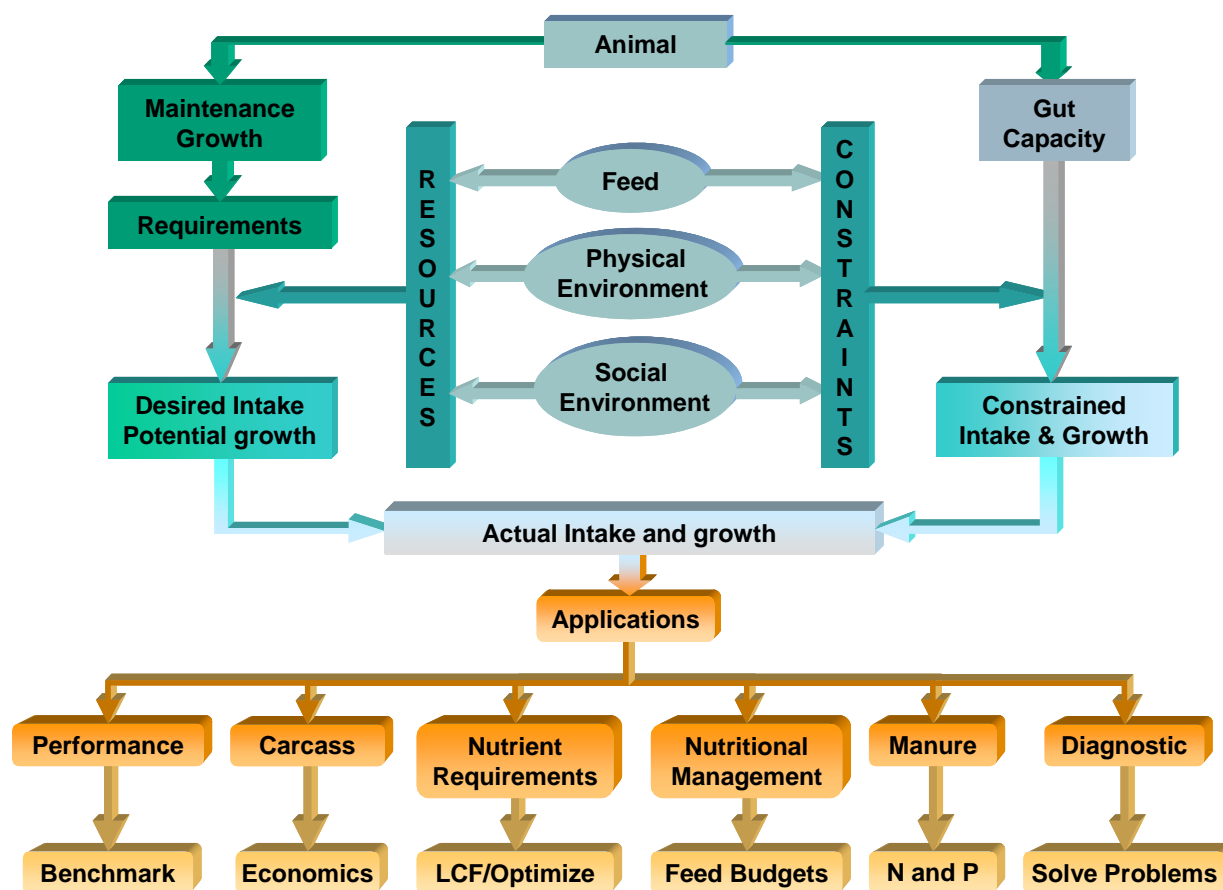
The ability to predict or simulate the optimum solution to an animal performance problem, financial outcome or nutritional requirement, depends on 1) the integrity of the input data used to define the original problem; 2) the accuracy of the system used to measure the biological responses, and 3) the expected outcomes to be reported. The integration of these three components, therefore, should form the foundation of any model or system used to predict animal growth. Simulation of swine growth for the purposes of predicting the responses of pigs to nutrient inputs has come a long way since the first conceptual frameworks were published by Whittemore and Fawcett (1976) and Emmans (1981). A number of models differing in complexity and application have been reported in the scientific literature each with their own description of growth and predictive objectives (Black et al., 1986; Pomar et al., 1991; Ferguson et al., 1994; Moughan et al., 1995; Birkett and de Lange, 2001; Green & Whittemore, 2003; Wellock et al., 2003). The successful application of these models into practice has varied due to their complexity, ease of use and the robustness of their scientific theory under commercial conditions. Despite the varying degrees of success, there is no doubt that the integrated approach to predicting growth and feed intake, significantly enhances the management decision-making process and allows for the prediction of optimum solutions in grower-finisher production. By rapidly quantifying both the technical and financial outcomes to production stimuli, the need for educated guessing is eliminated. It is

for this reason that Watson[®] was developed as a decision-making tool to improve the performance and productivity of hog finishing operations.

WATSON[®] OVERVIEW

Watson[®] was developed by integrating the science and practice of pig production into an easy to use Web-based software application. The science and theoretical framework has been published (Ferguson et al., 1994; Wellock et al., 2003) and extensively validated, with over 20 trials conducted to test significant drivers and components of the model. Its framework is unique and flexible to allow the prediction of voluntary feed intake, as well as predicting performance and financial outcomes reasonably accurately under commercial conditions. For a detailed description of the program refer to Ferguson (2006). The key components and the commercial applications of the model can be summarized in Figure 1.

Figure 1. The framework summarizing the key components and commercial applications of an integrated management model (Watson[®]).



The main purpose of an integrated management model is to bring together the complex interactions between the animal, its environment and its diet, into a system that will accurately predict the animal's performance under commercial conditions. Applying this technology will predict 1) the cause-and-effect responses to changes in the production environment; 2) the subsequent financial implications of these changes; and therefore, 3) the optimum nutritional and/or financial strategy, unique to the individual producer. It is important to note that optimum solutions are farm-specific and no one solution fits all because of the inherent differences in production characteristics on each farm (e.g health status, genetics, housing, ingredient/feed costs).

OPTIMUM SOLUTIONS

Nutrition Strategies

Some of the nutrition strategies that can be optimized include: 1) nutrient requirements based on a) the producer's objective (economic or performance), b) different feed budgets, and c) different nutrient density of the diets; 2) minimizing under and over-feeding nutrients; and 3) the use of ractopamine (e.g Paylean®). Of particular importance is the ability to define optimum nutritional strategies based on current feed ingredient prices as well as future ingredient prices. Therefore, responses in gross profit to changing energy density and/or the lysine:energy ratio of the diet can be predicted over time and the results used to change the nutritional strategy to maintain the optimum solution.

Feeding Management Strategies

A feeding budget should be designed and implemented to optimize the producer's objective (which could vary from higher gross profits per pig or per annum, lowest feed costs/kg gain, faster growth rates or best feed efficiency). Using an integrated management model it is possible to predict the optimum feed budget based on cost versus nutrient requirement for any growth period. This is done by comparing the performance and financial responses to different diets and their respective feed budgets, and allowing the producer to select the feeding program that best meets his/her production objectives.

One of the consequences of being able to predict daily feed intake and body tissue deposition is the ability to dynamically determine the amount of nutrients excreted, especially nitrogen and phosphorus excretion. With each simulation it is possible to determine the total amount of N and P that is excreted per pig per closeout period. Where N and P excretion are closely regulated, Watson® can be used to develop feeding programs, including diets and feed budgets, that will reduce their excretion. A simple example is moving from a 2-phase to a 3-phase feeding program can reduce N excretion by 90-160g/pig which translates into a 240-430kg N reduction per year, respectively, for a 1000 pigs per closeout barn.

Integrated management tools are also helpful in identifying production problems, provided the simulation process is performed on a daily basis. Examination of the daily predicted results can assist in identifying constraining factors that are possibly limiting performance.

Appropriate corrective action to these production problems can then be developed and implemented.

Financial Strategies

Fundamental to any economic optimum solution in finishing hogs is the incorporation of a predefined grading grid and the variation of the carcass components, used to determine the index and/or bonus incentives, associated with a group or population of pigs shipped to market. Accurate estimates of the variation of carcass weight, lean yield, back fat and loin muscle depth are key to the accuracy of determining profit or loss margins. Fortunately, reasonable estimates of these deviations can be calculated from the data sheets the producer receives from the slaughter plant(s). With Watson[®] it is possible to simulate market performances for any predefined grading grid and thereby determine the financial consequences of any production change such as feed costs, health, stocking density and housing, genetics and marketing. For example, it is possible to determine the optimum average market live weight a producer should target at present, which may or may not be the same live weight in a year's time. Clearly, as feed and hog prices change so too will the optimum marketing strategy change for a producer (Figure 2).

Figure 2. Predicted market weight response to changes in feed prices for different processors when hog prices are \$1.10/kg. (Low = -\$30, High = +\$30/MT).

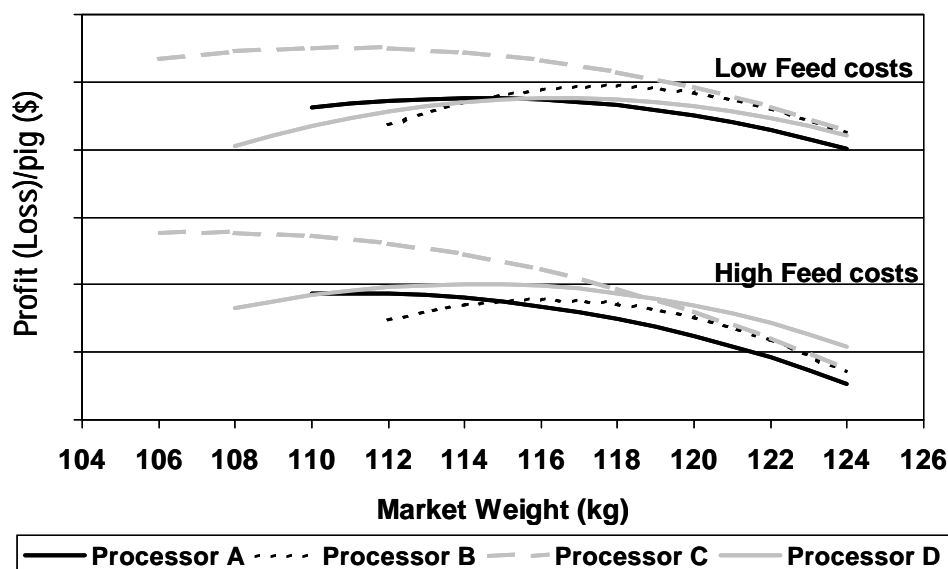


Figure 2 indicates that the average hog shipping weight, to provide the highest gross profit, may be lower (-4 kg) when feed prices move up. Similarly, Table 1 illustrates the effect on margins when there is a simultaneous change in both feed and hog prices. The extent of the change will depend on the specific packer to which the hogs are being shipped. There are also opportunities to ship barrows and gilts at different weights. Once again the optimum market strategy will be producer-specific because of the unique production characteristics of each farm.

Table 1. Predicted relative losses associated with shipping to a fixed market weight when hog and feed prices change.

Scenarios		Processor A (117 kg)		Processor C (114 kg)	
Hog Price	Feed Costs	Loss/Pig \$	Optimum Wgt kg	Loss/Pig \$	Optimum Wgt kg
Average		0	117	0	114
Low	High	-\$1.39	110-112	-\$1.61	106-109
Low	Low	-\$0.28	113-116	-\$0.33	109-112
High	High	0	115-118	0	113-116
High	Low	-\$0.33	118-121	-\$0.49	116-119

(Average: Hog Price=\$1.50, Feed costs = \$230-\$250/MT; Hog Price: Low = \$1.10, High = \$1.70; Feed Costs: Low = -\$30, High = +\$30/MT).

CONCLUSIONS

To successfully produce pigs in an increasingly volatile market, attention will need to be directed toward developing optimum nutrition, management and financial strategies through more informed decision-making processes. Therefore, the ability to make better decisions in this constantly changing production environment will become increasingly dependent on the application of integrated management models, like Watson[®]. These integrated systems can dynamically simulate the whole production process and thereby predict the cause and effect responses to the specified driver(s) of change, and attach a financial consequence to the decision-making process. This will enable and empower producers to develop their own optimum solution to their specific production system.

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NUTRITION SOLUTIONS FOR GROWER-FINISHER PIGS

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INTRODUCTION

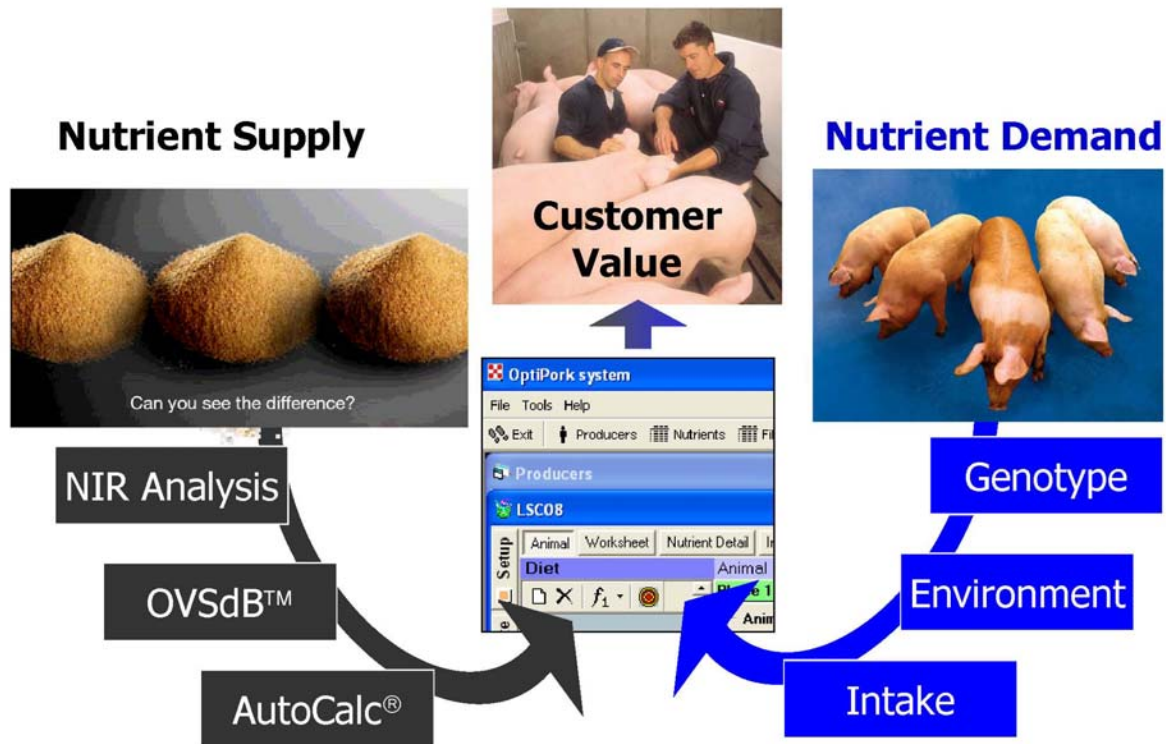
We may have little control over the market forces that shape the current calamity in the swine industry but optimized barn management will help to reduce red ink at the farm. In an effort to lower production cost many factors can be modified and feed costs, representing the single biggest expense, are one obvious area to constantly examine. However, as Denis Dipietre recently outlined, it is profit that you are trying to impact and this has two parts: revenue and cost. It is crucial to understand how your cost cutting measures impact revenue and implement only those that truly improve revenue. Cost cutting measures that decrease revenue to the point that the realized savings are offset must be avoided.

YOUR FARM IN A VIRTUAL WORLD

It is not easy to identify the most economical feeding and production strategy for a grower barn at the best of times. The recent dramatic increase in the cost of traditional feed ingredients and the current hype about by-products from the production of bio-fuels have added further to the complexity. Which alternate ingredients should I consider? Should I buy distillers and which supplier offers the product with the most value and the least variation? What nutrient specs are the most profitable with the current economics for my genotype and my barn environment? At what weight should I ship my pigs? These are just a few of the questions that producers have to find answers for in an increasingly more complex and faster changing market environment.

Agribands Purina uses a patented business process (Burghardi et al., 2005) that leverages nutritional innovation to provide unique customer solutions. At the heart of this process is the Optipork system that simplifies finding the right solution for your operation. By building your farm in a virtual world, Optipork links a set of ingredient valuation tools to nutrient supply and sophisticated modeling defines the pig's nutrient demand. This virtual farm puts animal requirements in the context of ingredient valuation, diet formulation, performance projection and profitability (Figure 1).

Figure 1. Connecting nutrients.



THE INGREDIENT VALUATION TOOLS

Even seemingly consistent ingredients such as corn and soybean meal are a source of nutrient variation in your business. Variation due to growing season, processing changes, fineness of grind and many other factors change nutrient levels and ultimately animal performance. By-products from bio-fuel production or other sources exhibit even greater nutrient variability. Careful understanding and disciplined measurement of incoming ingredients increase the probability of achieving the expected animal performance and business results. To help producers discover the best value ingredients Purina offers leading-edge, practical tools to assist your efforts:

- A sophisticated local laboratory equipped with NIRA technology to allow quick turn around on submitted samples.
- Optimum Value Supplier Database™ (OVS) system helps manage the analytical information we continually collect on ingredients identified by supplier and location.
- Grain Particle Scorer™ tool that provides an easy on-farm measurement of particle size, allowing adjustment of nutrient content and diet formulation.
- AutoCalc® system to calculate nutrient levels of various ingredients.

These tools coupled with our nutrient vocabulary (e.g. net energy, standardized ileal digestible amino acids, digestible phosphorus) make up the nutrient supply chain inputs for Optipork.

THE NUTRIENT SUPPLY CHAIN

Pigs require nutrients and not ingredients, making an accurate evaluation of an ingredient's nutrient profile the basis of every feeding program. The Purina Central Lab in Strathroy offers analysis for both wet chemistry and NIRA (near infrared analysis) whereby the latter provides customers with a quick and accurate means of analysis. Besides traditional nutrient analysis Purina research has also developed quick tests such as the amino acid digestibility index that provides an estimate of amino acid digestibility in ingredients. Such assays are of particular value with processed by-products like distillers where over-heating may damage and reduce available nutrients.

Analytical results from the laboratory are added to our OVS database of ingredient nutrient profiles, which represents a unique approach in collecting and summarizing ingredient values by suppliers. The database provides historical data on nutrient content that we can help you leverage into procurement and diet formulation. Because the database is anchored in lab analysis for each ingredient from each supplier's processing plant, each ingredient source is unique when setting up your formulation. You don't just have one distillers. You have as many as you have unique distillers suppliers – a reflection of the real world. For each supplier we know average nutrient values of ingredients as well as expected variation. Thus, our OVS database helps you identify the highest value supplier.

Particle size of farm ground grain is well known to affect digestibility and thus performance. But only a tool such as the Grain Particle Scorer™ allows us to make the practical link. Placing a small sample of ground grain over a predefined screen separates fine and coarse particles. This simple analysis determines the particle score for that ingredient. Based on this score, the AutoCalc® system adjusts the nutrient profile in OptiPork. The AutoCalc® system provides a simple and dynamic means to adjust over 150 nutrients from an ingredient analysis of just a few key nutrients. Our laboratory spends considerable time to ensure that the complex equations in AutoCalc® – based in wet chemistry and animal digestibility studies – correctly update the nutrient levels real-time.

DEFINING NUTRIENT DEMAND

In addition to nutrient supply the OptiPork system estimates nutrient requirements using inputs on environment and animal performance. Key inputs to define animal performance are sex, feed intake and fat-free lean growth. Under commercial conditions, feed intake is clearly influenced by multiple factors such as environmental conditions (e.g. temperature), animal status (e.g. health) and feed (e.g. feed bulkiness). However, their interactive effects make reliable predictions extremely difficult and feed intake should thus be monitored (Nyachoti et al., 2004). Observed feed intakes, combined with some measurements of environmental conditions, can then be used to make projections for future feed intake levels. To describe environment conditions OptiPork requires inputs such as effective ambient temperature, floor type or pig density. Farm-specific fat-free lean tissue growth rates are established using available carcass data. OptiPork thus facilitates the design of diet changes over time and allows managing the process to get the right feed to the right pig at the right time.

CONCLUSION

OptiPork is a patented business process that leverages our nutritional innovations to provide unique customer solutions. The system has the capacity to identify cost effective ingredients and suppliers, to accurately update nutrient profiles of ingredients and to adjust nutrient specifications to reflect current economics. With accurate prediction of animal performance and calculation of feed budgets OptiPork provides the power to discover the best feeding program for your pig in the current market environment.

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ALTERNATIVE SOURCES OF ENERGY – ON-FARM OPTIONS

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WHAT IS BIOGAS?

Anaerobic digestion (AD) is the process by which organic materials in an enclosed vessel are broken down by micro-organisms, in the absence of oxygen. Anaerobic digestion produces **biogas** (consisting primarily of methane and carbon dioxide). AD systems are also often referred to as “biogas systems.”

Depending on the system design, biogas can be combusted to run a generator producing electricity and heat (called a co-generation system), burned as a fuel in a boiler or furnace, or cleaned and used as a natural gas replacement.

The AD process also produces a liquid effluent (called digestate) that contains all the water, all the minerals and approximately half of the carbon from the incoming materials.

Many agri-food AD systems are located on farms. Farm-based AD systems work well with liquid manure. AD systems provide a valuable manure treatment option.

For hog operations:

Cons:

- Concern that high nitrogen content in manure will inhibit AD process
- Recipe is key (probably not pure hog manure) - add off farm material
- Typical under barn storage: not fresh manure, need long term storage

Pros:

- Decent biogas output: (m³/tonne wet material)
 - Liquid hog manure: 20-35 m³/t
 - Dairy manure: 20-30 m³/t
- Potential use for heat byproduct in new barns

ENERGY CROPS/ OFF FARM MATERIAL

- High energy-density compared to manure
- Greatly increases energy production compared to manure system
 - Corn silage: 170-200 m³/t
 - DAF from meat plant: 35-280 m³/t
 - Restaurant and bakery waste: 50-480 m³/t

CHALLENGES OF ANAEROBIC DIGESTION OF MANURE

Although the fundamentals of AD systems are very simple, the operation and control can be complex. Management considerations include:

- mixing primarily fresh organic material (<1 week old) so that optimum organic matter is available for digestion
- maintaining a narrow temperature range suitable for digestion — adding material that has already cooled down in the barn or storage will increase the heating requirements
- completing proper physical design of the system to eliminate plugging, crusting or foaming problems
- optimizing the “recipe” to generate sufficient and consistent biogas production to make the economics work
- installing and managing an interrelated group of systems to safely handle heating of the tank, material flow, hydrogen sulphide reduction, methane transfer, heat production, electrical production, interconnection with the electrical grid and surplus heat management

ELECTRICITY CONSIDERATIONS

Interconnection to the Electricity Grid

When AD systems are designed for electrical production, the system typically generates more energy than can be used on that one site. Even in cases where energy production matches on-site energy needs, an interconnection with the grid is useful. Energy demands at most facilities are not typically static or linear. Under normal conditions, there are peaks in energy demand that the AD co-generation system may not be responsive enough to supply. Instead, the grid essentially acts as a large battery, with the AD system putting energy in and the local facility drawing energy out.

Net Metering

Net metering is an agreement where the energy generator (the AD operator) pays the electricity distributor only for the net amount of electricity consumed. This allows the AD facility to generate electricity at any time, send it into the grid and then use electricity at any other time. The net billing or reconciliation is typically within a specified period of time (1 year in Ontario). The electricity distributor bills the facility for the net amount used. See the Ministry of Energy’s Net Metering brochure for more information: www.energy.gov.on.ca/english/pdf/renewable/NetMeteringBrochure.pdf.

Standard Offer Program

The Renewable Energy Standard Offer Program (RESOP) gives some renewable energy system operators, including AD system operators, the option to sell or replace electricity at fixed rates for a period of 20 years. At the time of writing, the value of the electricity is

around 11¢/kWh for non-peak electrical consumption periods and around 14.52¢/kWh for peak periods (2,000 hr/yr). These values will inflate at 20% of the Consumer Price Inflation Index. For more details, see the OMAFRA Factsheet *Anaerobic Digestion and the Renewable Energy Standard Offer Program*, Order No. 07-051, or visit the Ontario Power Authority (OPA) website.

On-Farm Mixing of Off-Farm Source Material

Mixing of off-farm source material with manure in an “on-farm mixed anaerobic digester” may increase biogas production. Some European jurisdictions allow mixing of up to 25% of off-farm source materials such as fats, oils and greases, pre-consumer food wastes, and other food products or byproducts. As a result of the high carbon content of these materials, biogas production can be doubled or tripled depending on the quantity and quality of the feedstock. Proper storage of off-farm source materials is necessary to minimize the potential for odour nuisance. In addition, a blend tank may be necessary, depending on the type of AD system used. There are two regulatory systems to bring most off-farm source materials to a farm for mixing with manure in a digester: a Certificate of Approval under the *Environmental Protection Act*, or an approval under the Nutrient Management Regulation 267/03. Both of these regulatory systems have requirements for the facility and for the land to receive the end product.

FUNDING PROGRAMS

Ontario Biogas Systems Financial Assistance Program Field Day

The Ontario Biogas Systems Financial Assistance Program is a \$9-million investment that will help farmers and agri-food businesses develop and build generating systems that produce clean energy, reduce electricity costs and contribute to local economies. Funding is on a first come basis.

- There are two phases to the program. Phase 1 funding will cover up to 70 per cent of the eligible costs of carrying out a feasibility study, to a maximum of \$35,000. Last date to apply is September 30, 2008.
- Phase 2 funding will cover up to 40 per cent of eligible construction and implementation costs. The maximum total feasibility and construction cost funding is \$400,000 for each anaerobic digester system. Last date to apply is September 30, 2009.

Applications

Program guidelines and application forms for the program are now available online or by contacting:

Ontario Biogas Systems Financial Assistance Program, Ontario Ministry of Agriculture, Food and Rural Affairs. 1 Stone Road West, Guelph, Ontario N1G 4Y2, Tel: 1-888-466 -2372, E-mail: biogas.program@ontario.ca, Website: www.ontario.ca/biogas.

ELECTRICITY RETROFIT INCENTIVE PROGRAM (ERIP) - HYDRO ONE

Agriculture Program:

- Swine heat pads (less than 100watts), (\$45-\$90) heat pads controllers, (\$140) and high temperature cut off thermostats (\$90)
- Livestock water bowls (under 250 watts, minimum of 2 ' insulation) (\$40)
- Ventilation fans (24 ") (\$ 50)
- Photocell and timer for lighting control (\$25)

Contact Information : Contact person: Paola Silli

Program Coordinator, Conservation & Demand Management

Tel: (416) 345-6036 Fax: (416) 345-5911 E-mail: Paola.Silli@HydroOne.com

Industrial/Commercial /Institutional Solar Thermal Heating Grants

The Ontario government is making \$14.4 million available over four years to encourage the industrial/commercial/institutional sector to convert to solar thermal heating. Ontario businesses, industries, schools, universities, municipalities and hospitals would receive 25 per cent of the cost of the installation of a solar thermal heating system from the province to a maximum of \$80,000.

The program is linked with the federal government's ecoENERGY Renewable Heat Program which will also provide a contribution of 25 per cent to a maximum of \$80,000. It is estimated that the program will generate 500 installations over four years. **To access the provincial grant you must first access the federal grant program.**

Qualifying details (and other key FAQ's) can be found at: www.ecoaction.gc.ca/ecoenergy-ecoenergie/heat-chauffage/conditions-eng.cfm#3.

Class 43.1/43.2 Accelerated Capital Cost Allowances (ACCA) and The Canadian Renewable And Conservation Expenses (CRCE)

Class 43.1 and Class 43.2, in Schedule II of the Income Tax Regulations, allow taxpayers an accelerated write-off of the capital cost of certain equipment that produces energy efficiently or produces energy from certain alternative renewable sources. The write-off rates for Class 43.1 and Class 43.2 are 30 percent and 50 percent respectively, on a declining balance basis.

RESOURCES

- Biogas Program Website, Q&A - www.ontario.ca/biogas
- General Biogas System Info - OMAFRA Energy Website: www.omafra.gov.on.ca/english/engineer/energy.html
- OMAFRA staff (engineering, climate change, livestock, crop, food, land use planning, economic development, etc.)

- Agricultural Information Contact Centre Tel: 1-877-424-1300
- U.S. Environmental Protection Agency's AgSTAR Program
- Ontario Power Authority (OPA)
<http://www.everykilowattcounts.ca/HTML/BusinessPrograms/Agriculture/agriculture.shtml>
- OMAFRA. Poop Power 2004. Video outlining the operation of an on-farm Ontario anaerobic digester. Available on the OMAFRA website at www.ontario.ca/agengineering, under Alternative Energy — Anaerobic Digestion — Video
- AgriEnergy Producers' Association of Ontario (APAO). Associate Member Organization under the auspices of the Ontario Sustainable Energy Association (OSEA) since April, 2007.
 Tel: (613) 224-8308 Fax: (613) 224-1642 Website: www.apaeo.ca

CHALLENGES IN THE ANAEROBIC DIGESTION OF HOG MANURE

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BACKGROUND

Anaerobic digesters using hog manure as a primary feedstock have operational requirements different than those using dairy manure as a result of the diet of hogs as compared to dairy cattle. The mechanisms needed to facilitate the anaerobic digestion of hog manure are well understood and, as a result, many hog digesters are successfully operational in Europe. However, the extensive use of chemicals in hog barns needs to be assessed on a case-by-case basis in order to manage and/or mitigate their presence in the manure and, subsequently, the digester. This is of particular concern when disinfectant chemicals and antibiotics are used as they can be highly detrimental if present in a biogas plant.

Anaerobic digestion is a highly complex process containing an immeasurable quantity of biological and physiochemical reactions. These processes take place at the same time, inducing many different interactions between chemicals and microorganisms. While it is normal to have certain inhibiting substances in an anaerobic digester, such as ammonia, if the concentration of toxic substances reaches a critical level, anaerobic digestion and biogas production will stop. Consequently, an understanding of the toxic and inhibiting factors present in a biogas plant and their interaction with the digestion process is crucial for achieving optimal biogas production and economic returns.

An anaerobic digester is essentially a bioreactor containing several kinds of microorganisms, supplied through the introduction of sewage sludge or manure. Each microorganism has a different anaerobic metabolism and is sensitive to diverse physiochemical conditions. Consequently, the state of the biocoenosis depends on the composition of the substrates and how microorganisms themselves convert the given substrates. An abundance of nutrients and optimal environmental conditions result in the growing and reproduction of microorganisms, which in turn allows for a high conversion rate of substrates. However, if this conversion of substrates results in a lack of nutrients or an increased concentration of a critical chemical, some microorganisms will starve or be inhibited. Therefore a bioreactor is seen as a closed system where all components, whether chemical or biological, participate in one or more reactions to maintain system equilibrium.

In the fields of microbiology and environmental engineering, laboratory research is performed regularly to define the most important processes. As Genesys Biogas Inc. has found, these processes can be replicated by computer simulation.

WHY MATHEMATICAL SIMULATION?

As a result of relatively low energy prices in Canada, Biogas project developers were forced to use high strength feedstock in order to achieve adequate energy production, ultimately pushing biogas systems to their limits. Consequently, some equilibriums in the digestion process are shifted to a critical level that could endanger the methanization process or even the operation of the entire biogas plant. Predicting these cases of system decline or failure is essential for project financing. Traditionally, predicting either relies on time-consuming and expensive lab-tests.

To reduce costs and time, Genesys Biogas Inc. developed a mathematical model to simulate the anaerobic digestion process in order to predict the biogas yield and stability of the entire digestion process. The model is based on the Anaerobic Digestion Model No.1 (ADM1) of the IWA task group and the simulation is done with a program known as Aquasim. Genesys Biogas Inc. further developed ADM1 with several processes and adjustments concerning high strength substrates.

So far, biogas composition, biogas yields, pH, and levels of organic acids predicted by Aquasim have matched lab results quite closely. Aquasim further allows the identification of ammonia inhibition as a cause for increasing acetate concentration in the lab test.

RELIABILITY OF THE ANAEROBIC DIGESTION MODEL

The extended ADM was compared to different laboratory results to determine the accuracy of the computer modelling.

BMP Tests

The energy content of a substrate is usually determined by a laboratory batch digestion study, known as a Biochemical Methane Potential test (BMP). Genesys Biogas Inc. simulated BMP tests of two different high strength substrates:

- Substrate 1, a by-product from a milk processing plant.
- Substrate 2, a by-product of a down-stream process in the Bioethanol production.

Figure 1. Simulated biogas production compared to measured biogas production in the laboratory for the BMP test of substrate 1.

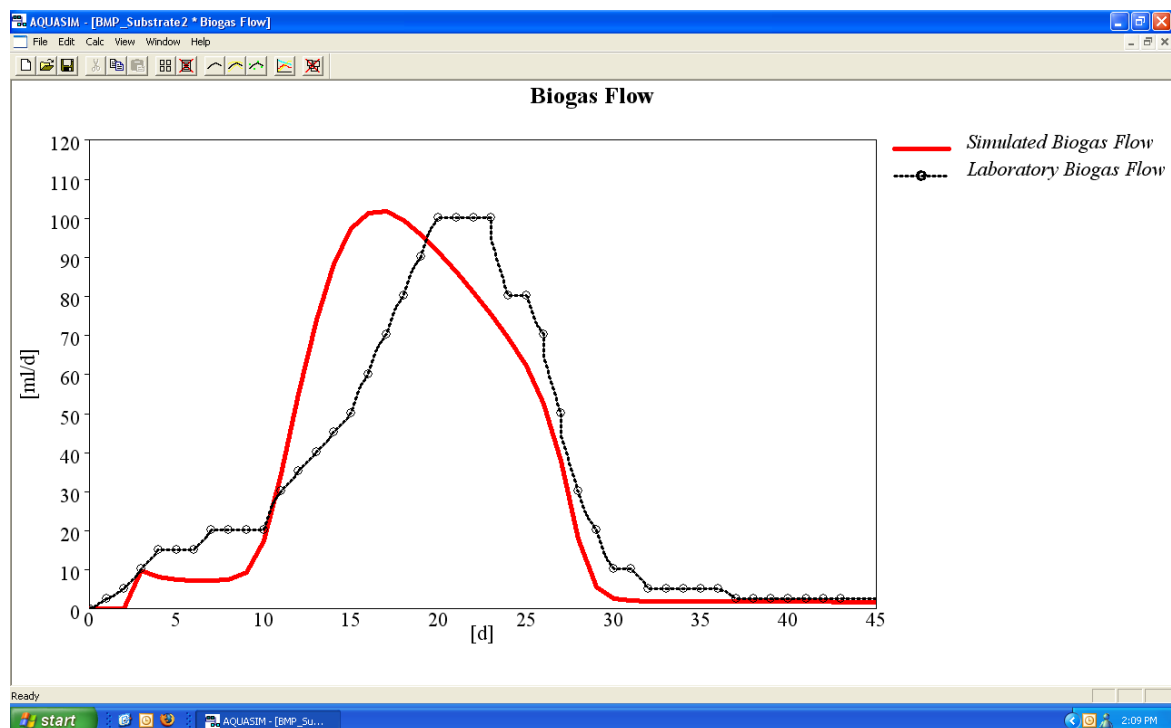
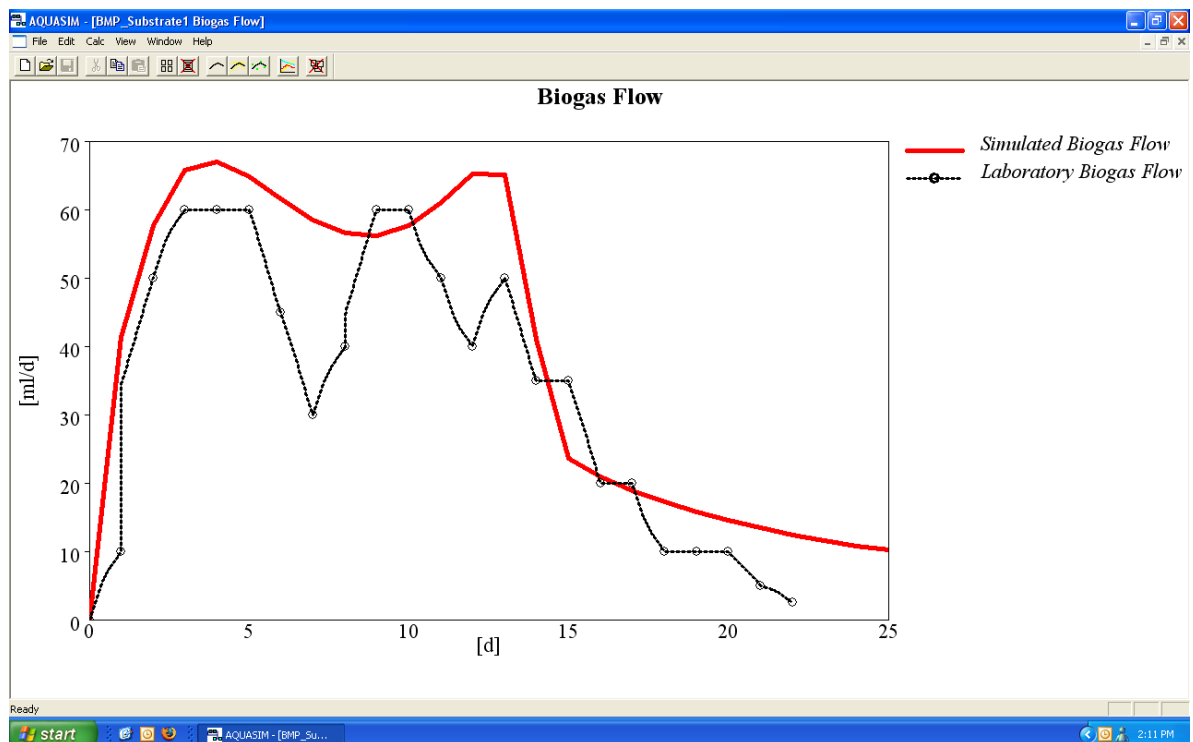


Figure 2. Simulated biogas production compared to measured biogas production in the laboratory for the BMP test of substrate 2.



Semi-Continuous Flow Digestion Study

The model was used to simulate a semi-continuous flow study of a Bioethanol by-product over 45 days. Prediction of levels of organic acids, biogas yield and pH are compared to lab results (Figures 3, 4 and 5).

Monitoring Study of Fepro Farm's Biogas Plant

Fepro Farm's biogas plant has operated on dairy manure for several years. The process is under steady state conditions. Based on the available data from the laboratory, values of organic acids and pH were compared to the simulation by Aquasim (Figures 6 and 7).

Figure 3. Simulated concentration of acetic acid and propionic acid compared to measured concentrations in the laboratory for the 4L semi-continuous flow reactor over 45 days.

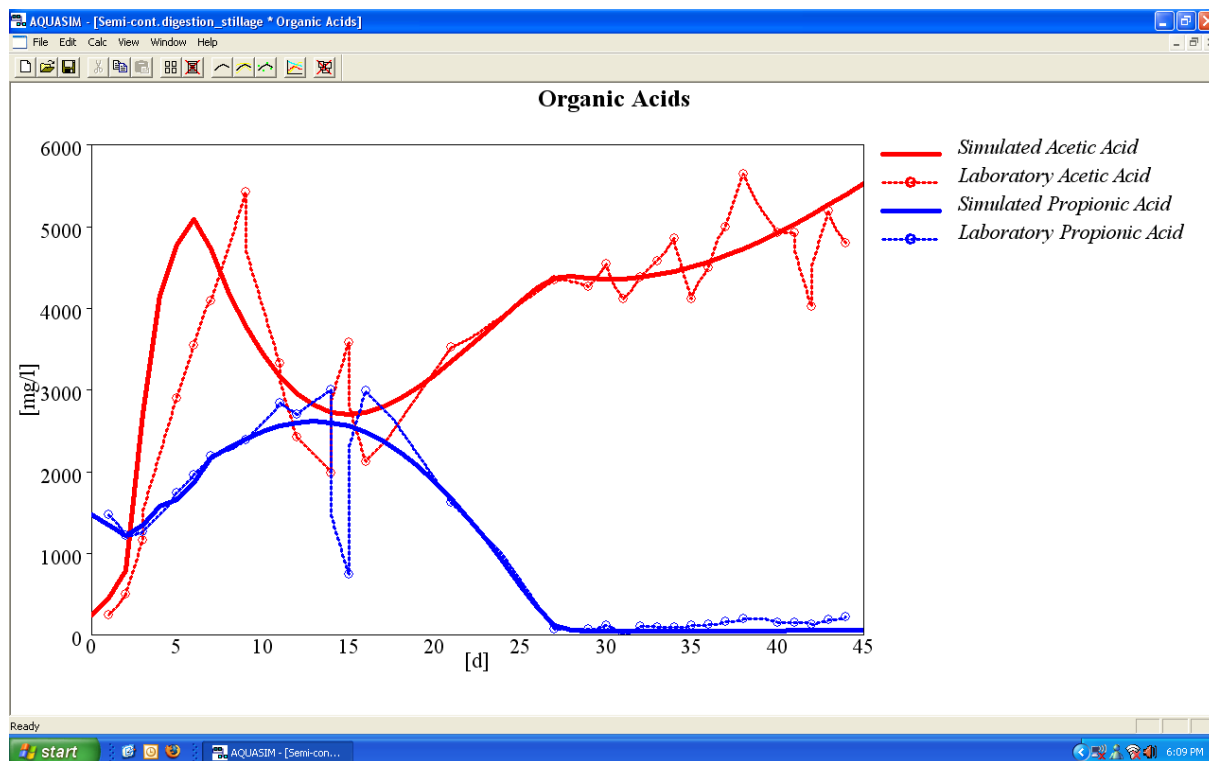


Figure 4. Simulated pH values compared to measured pH in the laboratory for the 4L semi-continuous flow reactor over 45 days.

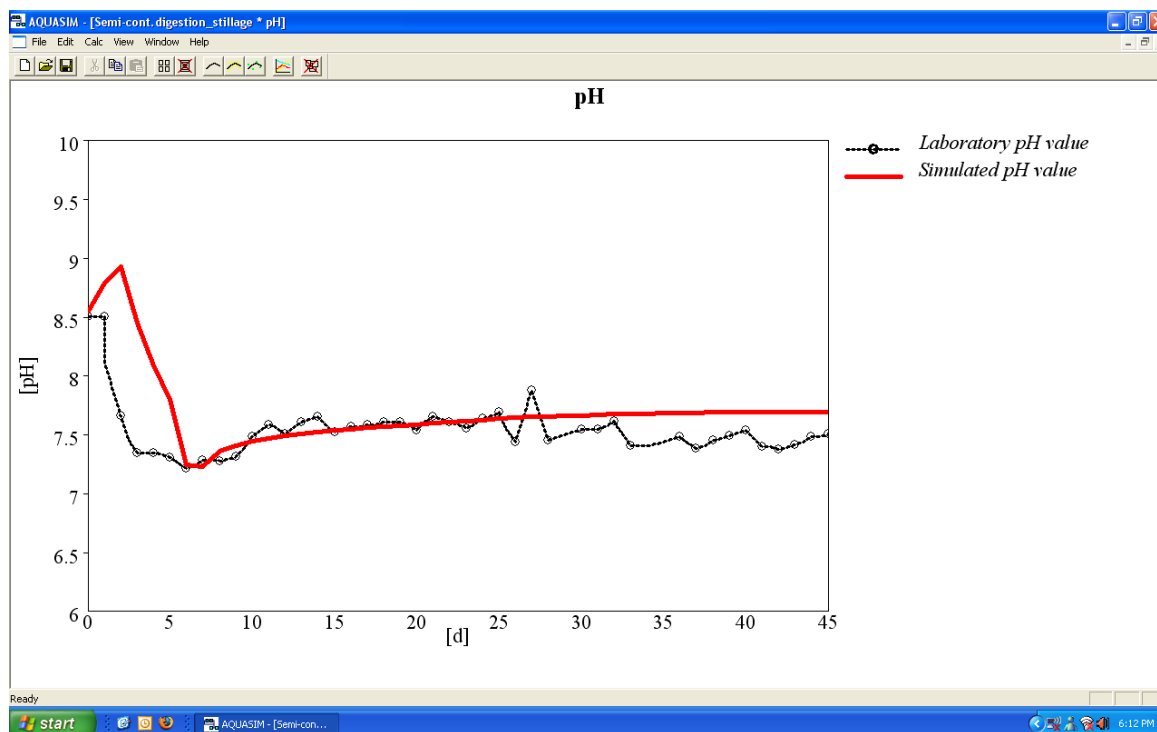


Figure 5. Simulated biogas flow compared to measured biogas flow in the laboratory for the 4L semi-continuous flow reactor over 45 days.

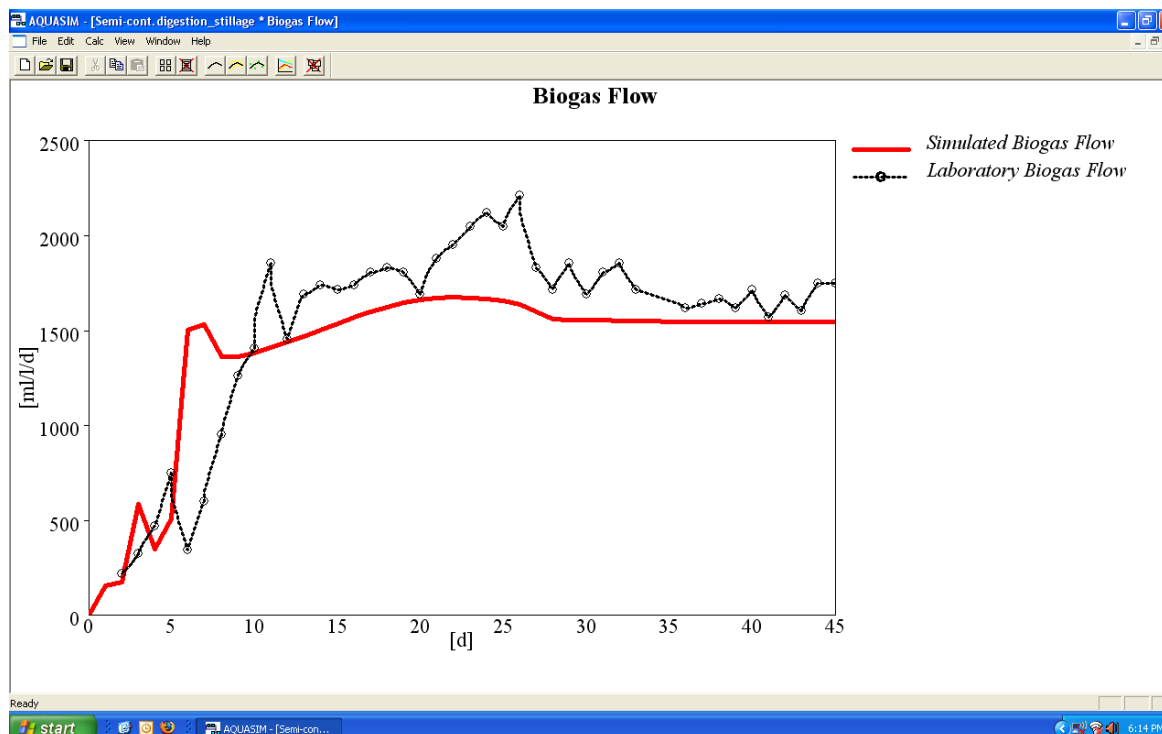


Figure 6. Simulated concentration of acetic acid and propionic acid compared to measured concentration in the laboratory for the Fepro Farm's biogas plant over 200 days.

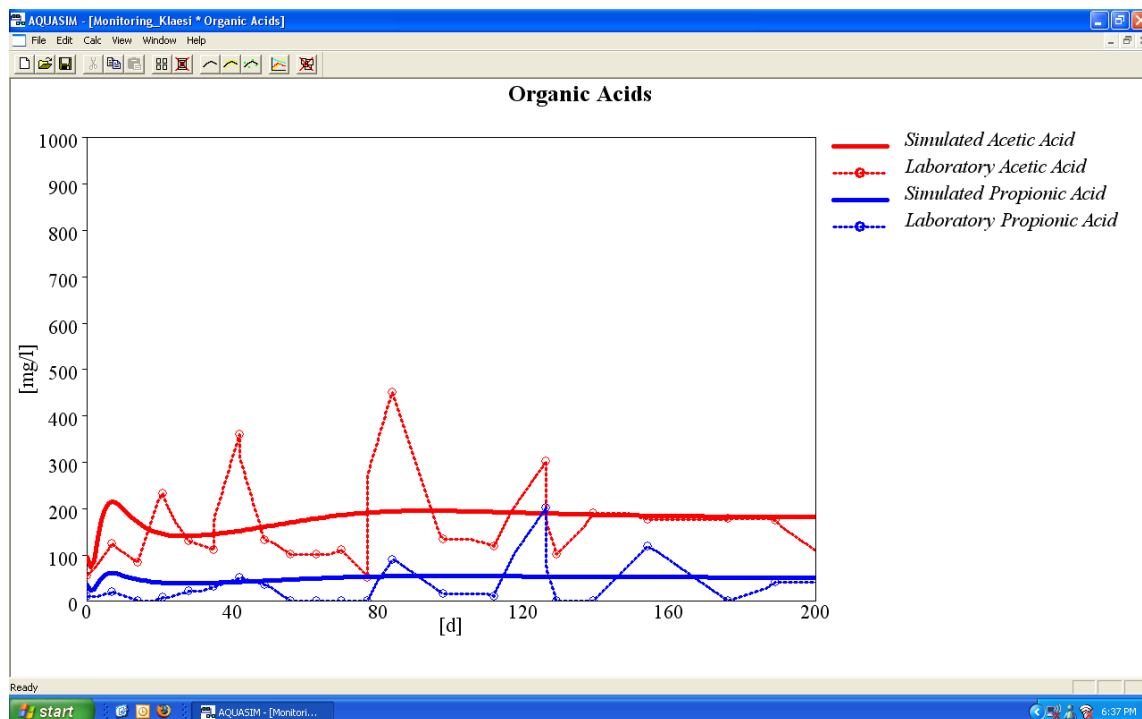
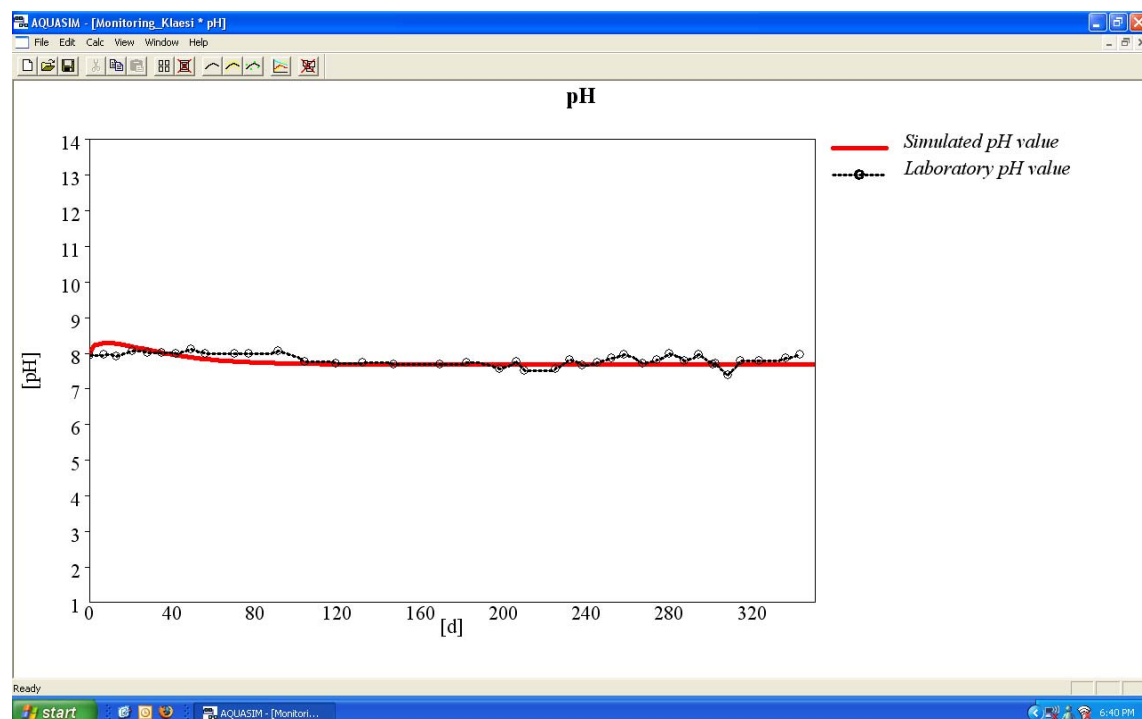


Figure 7. Simulated pH values compared to measured pH in the laboratory for the Fepro Farm's biogas plant over 340 days.



DISCUSSION / OUTLOOK

The modelling of the biological and chemical processes during anaerobic digestion creates a new opportunity to predict the potential and limits of high strength substrates. The enhanced model developed by Genesys Biogas Inc. produces an accurate description of the properties of potential biogas system substrates. This tool provides the opportunity to choose the most useful substrates in your area without time-consuming lab tests. Consequently, it reduces evaluation cost during project planning.

The main benefits for our clients are:

- Evaluation of new substrates with unknown behaviour
- Reduced cost for substrate evaluation
- Time benefit with few or no lab tests
- Process stability verification
- Prediction of critical components
- Establishment of operational safety margins
- Predicting steady state conditions including biogas yields of industrial organic by-products and its interactions with other substrates present
- Performance optimization of existing digesters
- Yield analysis and substrates behaviour of complex interactions in a digester
- Early warning systems for critical digester feed rates and problematic substrates
- Optimizing digester feeding regime, optimizing substrate blending in single stage and multiple stage digestion

Due to the immense number of biological and chemical processes within an anaerobic digester, this enhanced model has a great deal of potential for continued development. As a result, Genesys Biogas Inc. continues to refine the model in order to increase the accuracy of simulation and the diversity of its application.

APPLYING REPRODUCTIVE TECHNOLOGIES IN PRACTICE

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ABSTRACT

One of the most important aspects of applying reproductive technologies in practice is to determine whether they improve performance under farm conditions. What this really entails is conducting an “on-farm” experiment. Three of the most important aspects to consider when conducting “on-farm” experiments are the length of the treatment period; inclusion of a untreated contemporary group; and evaluating adequate numbers of animals. The length of the treatment period is determined by the specific physiological aspect that the new technology is supposed to influence. For example, technologies designed to increase the quantity and quality of sperm produced by boars need to be applied for at least 7 weeks because this is the normal length of time associated with spermatogenesis in swine. In contrast, technologies affecting the timing of estrus and ovulation only need to be administered for weeks or days because these processes occur over a shorter period of time. Inclusion of temporary, untreated groups is necessary to avoid confounding of results. Confounding refers to a situation in which two or more factors are altered at the same time which makes identifying the one that created a response virtually impossible. Finally, adequate numbers of animals have to be tested. This assists producers in determining whether any advantages in performance can be confidently attributed to the new technology or whether they are simply due to chance.

INTRODUCTION

Implementation of new reproductive technologies in swine production involves both basic and applied studies. Basic studies are typically done with small numbers of animals under very controlled conditions. They demonstrate that the technology being investigated influences biological mechanisms. For example, number of pigs born alive is a function of ovulation rate, fertilization rate and embryonic survival. Consequently, any technology designed to increase litter size has to improve one or more of these reproductive events in order to be effective. Basic studies essentially establish “why” or “how” new technologies work.

In contrast, applied studies are conducted with large numbers of animals under what is referred to as “field” or “farm” conditions. They provide critical information in terms of the range in responses that can be expected. For example, it has been well documented that parity structure, disease status, and season of the year all significantly affect how herds respond to a number of different treatments and, as a result, it is not unusual to see small or no responses on some farms, yet robust improvements on others. Applied studies help identify “when” and “where” on swine operations new reproductive technologies should be implemented.

If a producer reads about a new technology in a trade magazine or hears about one at a conference and decides to try and implement it on his or her operation, then he or she is conducting an applied experiment. In fact, most of the applied studies conducted with pigs probably are performed by producers who are interested in determining whether a new management practice, feed additive, or the like can improve their herd's reproductive performance. There is no single "right way" to conduct an "on-farm" experiment. However, there are several things that are common to all good studies. These include:

- a) treatment periods long enough to allow them to work biologically;
- b) contemporary groups that reflect normal, untreated management practices; and
- c) sufficient numbers of animals to accurately determine differences.

Careful attention to these three details will insure that the information producers collect and the decisions derived from it are accurate, unbiased, and apply to their farms.

LENGTH OF TREATMENT PERIODS

The length of the treatment period really depends upon the reproductive process that is trying to be improved, which requires some knowledge of the reproductive physiology of both boars and sows. Figures 1 and 2 summarize key reproductive events associated with production of spermatozoa in boars and live pigs in sows, respectively.

Figure 1. Schematic representation of sperm production in boars.

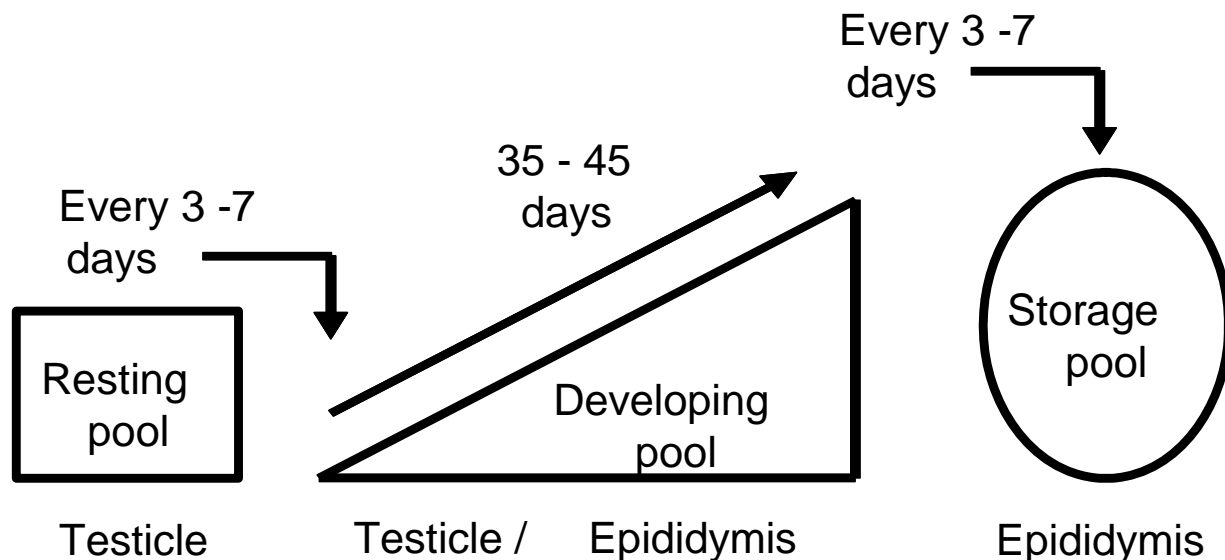
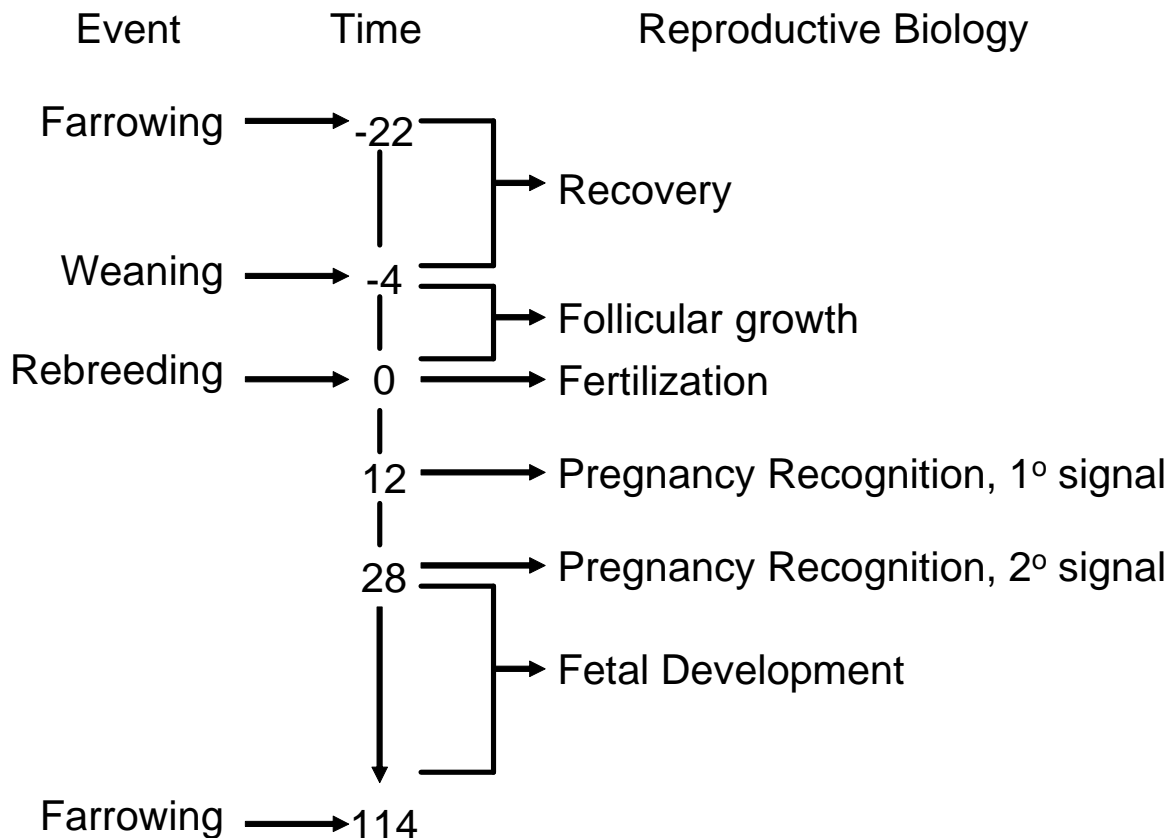


Figure 2. Schematic representation of key reproductive events in sows.



Production of viable, fertile sperm cells is referred to as spermatogenesis. In mature boars, every three to seven days, there is a new group of immature sperm cells that leave the resting pool located in the testicle and begin to mature or develop. While they are undergoing development, each sperm cell that left the resting pool divides repeatedly forming many new copies of itself. It takes between 35 and 45 days from the time sperm cells leave the resting pool until they are mature and capable of fertilization. Once the process is complete, mature spermatozoa are stored in the tail of the epididymis until they are released during ejaculation. It makes physiological sense that if a new group of sperm cells starts to mature every 3 to 7 days, then a new group of mature sperm cells enters the tail of the epididymis at the same frequency, 35 to 45 days later.

This information is important when applying reproductive technologies that are designed to increase the quality and/or quantity of sperm produced from boars. The three primary ways to increase the quantity of sperm cells boars produce are to increase the frequency at which new sperm cells begin to develop; decrease the length of time required for maturation; or increase the number of copies sperm cells make of themselves during development. Regardless of which of these are affected, it probably takes at least 6 to 7 weeks (35 days) after a treatment has been applied to observe any noticeable changes. This length of time is consistent with the normal maturation period of sperm cells. In other words, if one assumes that the application of the new technology coincided with a new group of spermatozoa entering the developing pool,

then it would be 6 to 7 weeks before this group of spermatozoa would be mature and reach the tail of the epididymis. These would be the first sperm cells that were exposed to the treatment throughout their entire developmental period.

In this time line, the day that the sow is rebred after weaning is considered to be Day 0 or the onset of pregnancy. Events that occur before and after breeding are designated with negative and positive numbers, respectively, in accordance with how long they occur either before or after the onset of pregnancy. The time line begins with the first day of lactation, which happens to correspond with the birth of the litter from the previous pregnancy and ends with birth of the litter from the current pregnancy. In essence, as soon as one pregnancy ends, physiological processes are initiated that begin to prepare a sow for her next one.

After farrowing, the reproductive system of sows requires time to recover from the previous pregnancy. The three most important organs involved with this process are the ovaries, brain, and uterus. The ovaries contain follicles, which grow in response to two hormones produced by the brain, luteinizing hormone (LH) and follicle stimulating hormone (FSH). These follicles will eventually ovulate after weaning and release their eggs to be fertilized during rebreeding. The ovaries recover very quickly and their follicles are capable of resuming normal growth, if properly stimulated, within a few hours after farrowing. The brain normally does not acquire the ability to produce sufficient levels of LH and FSH to support the final stages of follicular growth and ovulation until 10 to 12 days after farrowing. The uterus is where the majority of embryonic and all of fetal development occur during pregnancy. Its recovery also contains two phases, but requires between 14 and 16 days under normal conditions.

From a physiological perspective, fertilization requires that sufficient numbers of fertile spermatozoa be present in the oviduct several hours prior to ovulation. Consequently, from a management perspective, things such as semen quality, detection of estrus, and the technical competence of breeding technicians all play important roles in the relative success or failure of fertilization. However, provided that these are all done reasonably well, fertilization rates in pigs are usually very high, often exceeding 90%. Around day 12 of pregnancy, embryos begin to produce estrogens. If sows receive the first signal by day 12, then pregnancy is maintained. The embryos continue their development and actually begin to attach to the uterus, which is commonly referred to as implantation. Sometime after day 17 and before day 28 of pregnancy, the developing embryos initiate a second period of estrogen production. It is thought that this second pregnancy signal is associated with the development of the fetal portion of the placenta.

After day 30, when implantation is complete, the developing embryos begin to resemble live pigs so they are referred to as fetuses. For the remainder of pregnancy fetuses grow and develop and should reach a physiological state in which they are capable of surviving outside the uterus, around 114 days.

In comparison, the sow's reproductive cycle is more complex than the boar's. Thus, recommendations with regards to how long a treatment or technology should be applied vary considerably and really should be based on how the technology is thought to affect the sow's

reproductive physiology. This is one of the main reasons why basic research is so important and is usually conducted before applied studies. Without going into exhaustive explanations, some general recommendations for the length of time treatments need to be applied to sows in order to have a biological impact are outlined in Table 1. These should be viewed as recommendations and it is important to recognize that depending on how the treatment or technology affects the sow, then there could be significant deviations to these suggestions. For example, in theory, it is possible for a single injection of a pharmaceutical to stimulate a sow for several days, weeks, or months depending on how quickly it is cleared from the sow's body. A treatment or technology with these properties might only need to be applied once, whereas one that basically does the same thing but has a shorter biological half-life might need to be applied several times. Therefore, the term "effective period" is used in Table 1. This term refers to how long the treatment or technology would need to remain active in terms of affecting the sow regardless of how many times it needed to be actually administered to the sow.

A tendency that is common to farm studies is to apply the new technology to every animal on the farm at a given point in time; collect data for a specified period of time; and then compare the performance of the herd "before" and "after" the technology was implemented. This typically is very easy to implement, because all the animals in the herd either do or don't receive the new technology at the same time. This type of approach is valid if all the animals and everything about the production environment (feed, labor, temperature, disease status) remained constant for the duration of the evaluation period. Unfortunately, this does not happen very often, if ever, in practice. What usually happens in studies conducted in this manner is that changes over time in the production environment or the animals themselves that are unrelated to the treatment or technology can bias the outcome of the data. Animal and veterinary scientists call this "confounding". When two things are confounded, it means that they were changed or altered at the same time and there is no way of knowing if a response is to the result of the changes in one or both of them.

A good example of confounding is shown in Figure 3. This was a study that was conducted on a commercial swine farm to investigate the use of oxytocin as a pre-breeding treatment. The study was conducted a number of years ago when A.I. was first being implemented in the U.S. on a large scale. The rationale was that oxytocin stimulates uterine contractions and is a normal constituent of semen. Consequently, by giving it to the sow prior to breeding, it should facilitate uterine contractions and improve the transport of spermatozoa in the female reproductive tract during insemination, which in turn, should improve fertility. The study was actually conducted in a manner in which sows within parity groups were selected to receive or not to receive oxytocin just prior to insemination. In other words, a contemporary, untreated control group was included. These results are shown in Panel A. Panel B contains the same data, but it only includes information from the untreated group during the first half of the study and the treated group during the second half of the study – a situation that is analogous to beginning treatment of the entire herd at a single point in time and then making a "before" and "after" comparison.

Table 1. General recommendations for the effective period of selected reproductive technologies for sows.

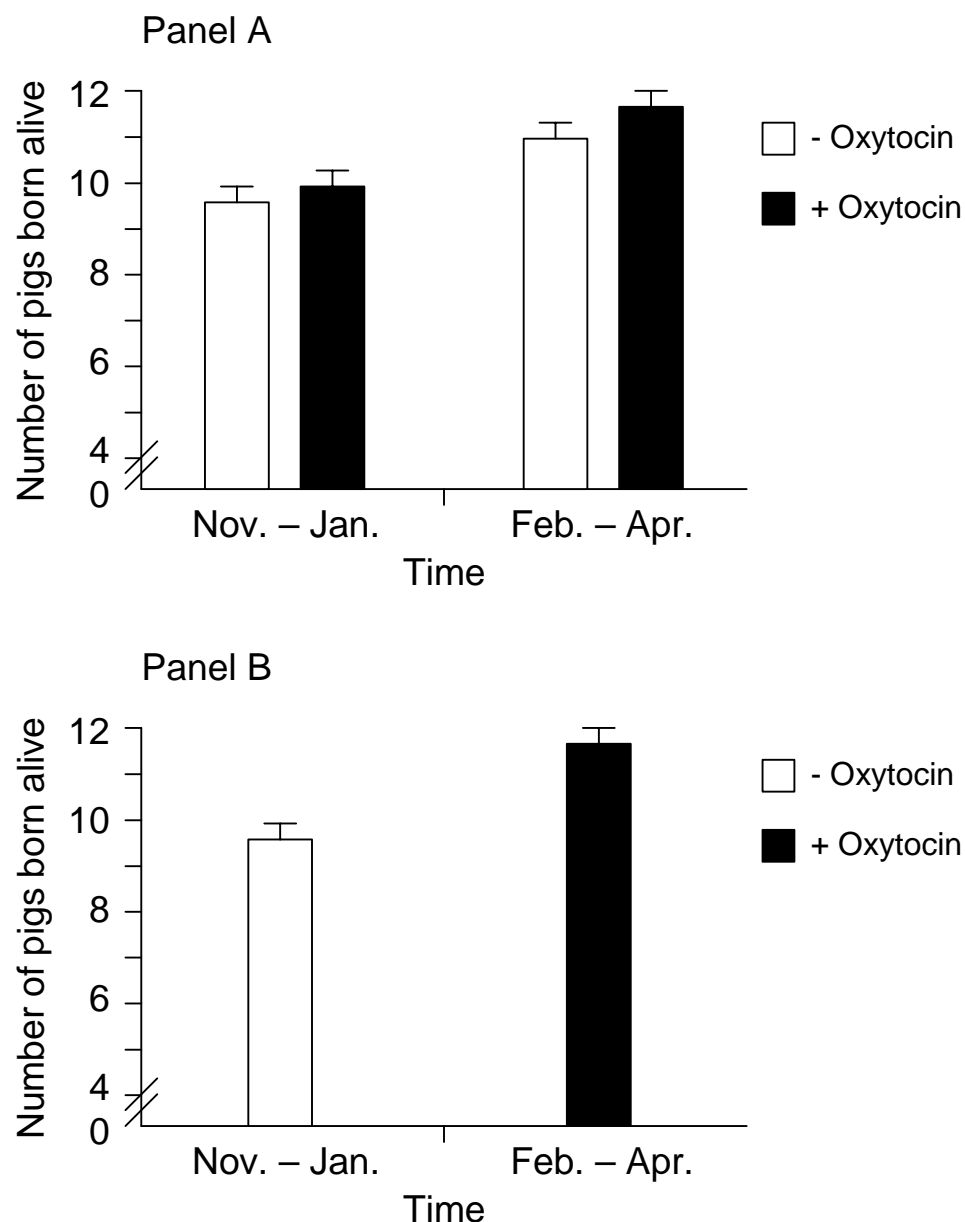
Goal of Technology	Effective Period	Rationale
Synchronization of Estrus	Between Weaning and Rebreeding	Final stages of follicular growth occur during this period
Synchronization of Ovulation	Between weaning and rebreeding but closer to rebreeding	Final stages of follicular growth occur during this period and ovulation occurs after estrus
Increase Fertilization	Rebreeding	Fertilization occurs over a 6 to 12 hour period during estrus
Increase litter size by affecting ovulation rate	Day 1 of lactation through rebreeding	Follicles ovulated after weaning begin to grow after farrowing
Increase litter size by directly affecting embryos	Rebreeding through day 30 of pregnancy	Critical aspects of embryonic development occur during the first 30 days
Increase litter size by directly affecting fetal development	Day 30 of pregnancy through farrowing	Fetal development begins after implantation and continues until birth
Increase litter size by directly affecting uterine function	Day 1 of lactation through the next farrowing	Uterine recovery begins during lactation and uterine function is necessary throughout all of pregnancy

INCLUSION OF CONTEMPORARY GROUPS OF UNTREATED ANIMALS

The results from the study with a contemporary untreated control clearly show that there was no difference between the two treatments. In other words, oxytocin pre-treatment did not affect litter size on this farm. However, the overall litter size did increase in both treatments over time. It was higher for sows bred between February and April compared with sows bred between November and January (Panel A). It is important to notice what the data would have looked like if the study was conducted in such a way that all the sows in the herd began receiving oxytocin in February and their performance was compared to sows receiving no treatment between November through January. Based on these data shown in Panel B, the conclusion would have been that oxytocin pre-treatment had a significant effect on number of pigs born alive. In fact the difference would appear to be almost 2 pigs per litter. Obviously,

something improved on a herd-wide basis with regards to the number of pigs born alive between the November/January and February/April. (In this particular case, it was due to the fact that the A.I. technicians became more comfortable with the insemination process, etc.). By including a contemporary control group of untreated animals, the conclusion from the study was that technology being evaluated, in this case, did not have an effect on reproductive performance. In contrast, without this group, the conclusion from the study would have been that the reproductive technology did increase litter size.

Figure 3. Effect of oxytocin pre-treatment on litter in swine. Panel A illustrates data analyzed with an untreated, contemporary control (correct design). Panel B illustrates how data would appear with a “before” and “after” comparison (incorrect design).



ADEQUATE NUMBERS OF ANIMALS

To determine whether new technologies should be adopted, it is important that they be tested on enough animals so that producers have confidence that any improvements seen are due to the technology and not other unrelated factors. As mentioned previously, parity structure, disease status, and season all affect reproductive performance and as a result farrowing rates and litter sizes often change over time within a herd. When a new technology is used, it is important for producers to know whether the advantages seen in the treated animals are due to the new technology or to unrelated, normal fluctuations that are present in every herd. There are three questions that producers need to consider when determining how many animals need to be tested in order to determine whether a new technology is working. These are as follows:

1. How large of an improvement does the new technology need to produce in order for it to be used routinely;
2. How much normal variation is present in my herd; and
3. How much confidence does one want in the results?

The answer to the first question is herd specific. Factors such as the cost of the new technology and the current level of performance in the herd are important considerations. Typically, there is a positive relationship between the cost of the technology and the level of improvement in performance that needs to occur. Technologies that are inexpensive probably do not need to produce as much improvement as those that are expensive. Indirect costs such as the labor required to implement a new technology should be considered as well. If additional labor is required to use something, then the actual cost to the farm will be higher than just the cost of the technology. Conversely, if a new technology reduces labor, then a higher initial cost might be justified.

The current level of performance of the herd also needs to be considered. Herds with low numbers have more room, or opportunities for increasing productivity compared with high-performing herds. The average litter size within a herd is a good example. It is unlikely that a herd with an average born alive of 13 piglets would be able to increase litter size by 1 pig per litter in response to a new technology. This is due to the fact that the biological limit for most modern maternal lines of sows is probably between 13 and 14 piglets. In contrast, an increase of this magnitude would be more likely in a herd that only averages 9 pigs born alive.

Knowledge of the normal amount of variation in a herd is important for the reasons discussed previously – producers need to know to what degree things such as parity structure and season affect performance in order to be confident that results they obtain from a new technology are in fact due to the new technology and not due to other unrelated changes inherent to the herd. The most common estimate of variation used is called the standard deviation. In statistical theory, the average plus or minus 1 standard deviation should encompass about two-thirds of the entire herd and the average plus or minus 2 standard deviations should encompass over 90% of the entire herd. For example, the standard deviation for litter size in most swine herds is around 2.0 pigs. For a herd with an average of 10 piglets born alive, on average, two-thirds of the litters farrowed would contain between 8 and 12 piglets and over 90% would contain between 6 and 14 piglets.

In general, there is an inverse relationship between the normal variation in a herd (as estimated by the standard deviation) and the level of management. In other words, as management expertise increases, the standard deviations for reproductive measures decrease.

The degree of confidence in the results deals with minimizing mistakes. There are two basic kinds of mistakes. One is the situation in which the new technology does improve performance, but the results from the study indicate that it doesn't. The second is the exact opposite – the new technology really doesn't improve performance, but the results from the study indicate that it does. Obviously, both are bad from a practical perspective. No one wants to use something thinking that it works when it doesn't. This simply wastes money. Conversely, if something really does work, then most producers would want to incorporate it into their management programs. These two types of mistake can occur for a number of reasons and from a statistical perspective the best way to minimize their occurrence is to test a sufficient number of animals. In general, there is a positive relationship between the level of confidence and the numbers of animals that need to be used when evaluating a new technology – producers that want more confidence in the results of their evaluations need to use more animals.

Relationships among normal herd variation, numbers of animals per treatment and the relative advantage that a new technology would need to produce in litter size are shown in Table 2. These calculations are based on a confidence level of 90%. One way to use this information is as follows:

1. Select the estimate of normal herd variation (standard deviation) in litter size that is closest to the herd in which the new technology is going to be applied;
2. Within that row, find the advantage in litter size that would make the new technology cost effective with the herd; and
3. Within that column, find the numbers of animals required per treatment.

For example, let's assume that a new technology becomes available and a herd with a standard deviation of 2.0 pigs wants to determine if it is something that they should incorporate into their normal management program. Let's also assume that based on their current level of production and production costs that the technology would have to increase litter size by 0.5 pigs. Table 2 indicates that they would have to collect litter size data from 200 untreated animals and 200 animals that received the new technology in order to determine whether it was effective at increasing litter size. After collecting the data from all 400 animals, if the average litter size from the animals treated with the new technology was 0.5 pigs or higher than the untreated animals, then the farm could be reasonably assured (90%) that the observed increase in litter size could be attributed to the new technology.

Table 2. Estimates of the relative advantage in litter size required of new technologies in order for them to be statistically significant (based on 90% confidence levels¹).

Herd Variation (Standard Deviation)	Numbers of Animals per Treatment			
	50	100	200	500
1.0	0.5 pigs	0.4 pigs	0.3 pigs	0.2 pigs
2.0	1.0 pigs	0.7 pigs	0.5 pigs	0.3 pigs
3.0	1.5 pigs	1.1 pigs	0.8 pigs	0.5 pigs

¹Power = 0.90 and $\alpha = 0.10$.

CONCLUSIONS

One of the most important and first steps for the successful application of new reproductive technologies is to evaluate their effectiveness on the farms in which they will be used. This involves conducting a “field study” or applied experiment. The length of time that they are applied to individual animals; measurement performance from a contemporary group of animals that are not treated; and monitoring an adequate number of both treated and untreated animals are necessary to evaluate whether new technologies actually improve reproductive performance.

QUALITY CONTROL OF EXTENDED BOAR SEMEN

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ABSTRACT

All boar studs should regularly monitor the extended semen doses produced and delivered to their customers by performing either internal quality control or by using a third party organization in order to make sure that all the doses have the best potential to impregnate gilts and sows inseminated artificially at the correct time in estrus. The quality control program should evaluate the number of sperm cells per dose, semen motility, semen morphology and screen for potential contamination by micro-organisms.

INTRODUCTION

The use of artificial insemination (AI) in the swine industry has grown & expanded very quickly in the last 15 years in North America. The genetic companies have boar stud centers strategically located across USA and Canada so they can promote and sell their specialized genetic lines to all the pig producers. The easiest way to introduce new genetics in a sow farm is select a genetic line and buy the extended semen from a boar stud for use in an AI program.

The contribution of a genetic company through extended semen produced in a boar stud is basically 50% of the input into a sow farmer's reproductive performance outcome (Althouse and Galligan, 2006).

The purpose of this article is to review the quality control (QC) analysis that should be done in the extended semen produced by any boar stud. The extended insemination doses will be used by pig producers and they must have the best characteristics to be capable of impregnating a gilt/sow bred at the appropriate time.

REASONS TO PERFORM QUALITY CONTROL OF EXTENDED BOAR SEMEN

To provide a product with the following characteristics for inseminating gilts and sows:

1. Absence of contagious organisms - disease
2. Maximum shelf life
3. Maximum fertility

In order to ensure these characteristics, boar studs must routinely verify the consistency of semen doses produced. They can choose either to perform quality control internally or use the services from a third party agent.

According to the industry standards, the characteristics to verify in each semen dose are:

- Accepted dose volume
- Accepted dose sperm motility
- Accepted sperm morphology parameters
- Accepted dose sperm concentration
- Accepted total sperm cells per dose (Althouse and Galligan, 2006)

The advantage of using a third party agent for this QC analysis is the neutral objectivity provided in the results.

QUALITY CONTROL TESTING STEPS

Number of Samples to be Tested and How Often

The samples to be tested (semen tubes, bottles or couchettes) must be randomly selected and the amount of testing samples depends on the quantity of semen doses (batches) produced daily by a boar stud. From a statistical perspective, in boar studs producing high quantity of batches/day, the quality control evaluation should be done based on a per 200 batch basis. For boar studs producing low number of batches/day, samples of the batches should be randomly taken and sent to the lab during the period of production of the 200 batches. The amount of batches that should be tested per 200 batches, with a 95% confidence interval and with 5 and 10% prevalence detection level is 51 and 27 respectively (Althouse and Galligan, 2006).

From the practical point of view, the ideal situation for a boar stud is to test the production of extended semen at regular intervals. Some boar studs have arrangements periodically with quality control laboratories to test batches of production every week, every 2 weeks or every 4 weeks following an annual predetermined schedule. This system allows them to monitor all the aspects of production periodically and any changes happening inside the boar stud unit could be reflected in the sample tested. For instance, changes happening in stud personnel, water purification-quality systems, hygiene & protocols for collection, equipment used for collection and semen processing, etc, can be reflected in the results observed in the semen samples tested.

Shipping

After a decision has been made about sending samples from a boar stud to a laboratory for quality control, the samples should be packaged inside a container such as double Styrofoam box system that contains cool gel packs at 17°C in order to keep the right temperature of the samples submitted. The samples should be sent to the final destination using an overnight courier. The shipping procedure should basically be the same as the one used for shipping semen from the boar stud to a regular customer.

Semen Temperature

As soon as the samples arrived to the laboratory, the arrival temperature should be taken using an appropriate instrument such as an infrared thermometer (Figure 1). The ideal arrival temperature should be between 16 and 18 °C. This evaluation will determine if the transportation/shipping system used by the boar stud is working correctly to maintain the appropriate temperature that semen requires, or if a change of protocol is required. It is important to remember that higher or lower temperatures than 16-18 °C could affect the sperm cells and cause reproductive problems when used.

Figure 1. Semen temperature evaluation using an infrared thermometer.



Dose Volume Assessment

In order to determine the volume of semen per dose, each container is weighted using a precision scale (Figure 2). It is considered that 1 gram of weight is equivalent to 1 mL of semen. The standard volumes being used in the swine industry for semen doses range between 60 and 80 mLs. Each boar stud tries to use the same volume in the doses being produced daily (i.e. 80mLs).

Figure 2. Dose semen volume analysis using a precision scale.

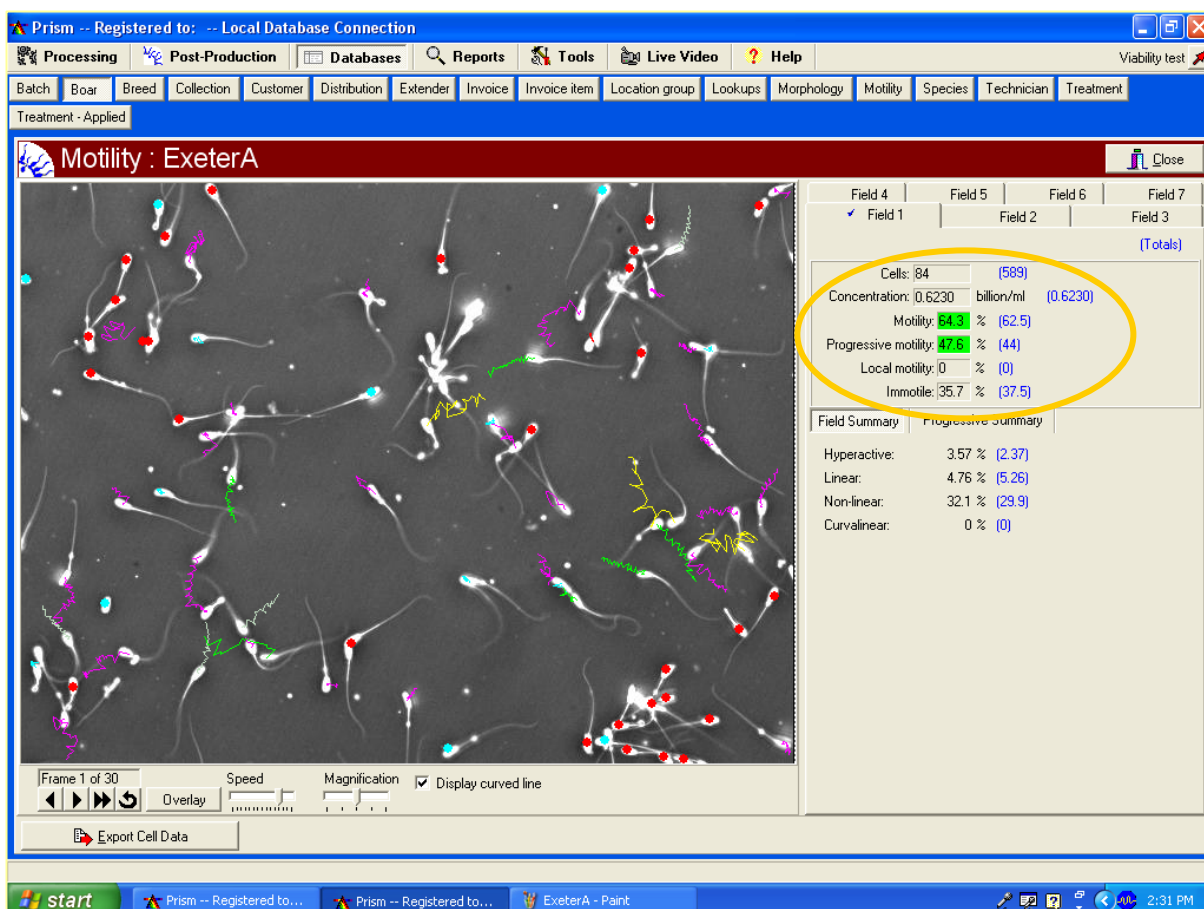


Individual Motility of Spermatozoa

The evaluation of individual sperm motility is used to determine the percentage of cells that are viable per dose of semen. The ideal way for performing this evaluation is by using a tool that in an objective way will tell us exactly how many and the percentage of sperm cells that are motile. There are presently Computer Assisted Sperm Analysis (CASA) systems available in the market such as the SpermVision. This particular CASA system has a camera connected to a computer that is placed on top of a trinocular microscope where the sample is being evaluated. The SpermVision camera is capable of taking 30 consecutive rapid photos of the sample field in 0.5 seconds, time that allows the computer to identify and capture individual sperm cells by its head size and analyze their movement pattern. Normally 7 microscope fields are evaluated per sample, to have an accurate evaluation of individual motility analyzed per sample. A sample is expected to have at least 70% motile sperm cells. It is also ideal if all the motile cells present in the sample have a straight movement, parameter known as “progressive motility” (Figure 3).

The percentage of individual progressively motile sperm cells can help to predict the sperm membrane integrity and morphological integrity of the cells present in the sample (Barth, 1997).

Figure 3. Screen of a semen sample being analyzed using the Sperm Vision CASA system. Please notice in the yellow circle the concentration and motility results.



Concentration and Total Number of Spermatozoa Present per Sample

The first step is to calculate the concentration of spermatozoa per mL of extended semen. Due to the high concentration of sperm cells in a semen dose, it is necessary to dilute the semen sample to a known dilution factor to decrease the sperm concentration so that individual cells can be counted manually. The sperm concentration/mL is then estimated by filling some of the diluted sperm solution in the haemocytometer (Figure 4) and counting the individual cells with a Phase contrast microscope (Figure 5). Then a mathematic calculation is done using a known formula that requires the dilution factor used and the cells counted. This technique is considered the gold standard for calculating concentration of cells per mL of solution.

The concentration/mL obtained with the hemacytometer is then multiplied by the total volume of the dose, which will provide us the total number of sperms present in the dose.

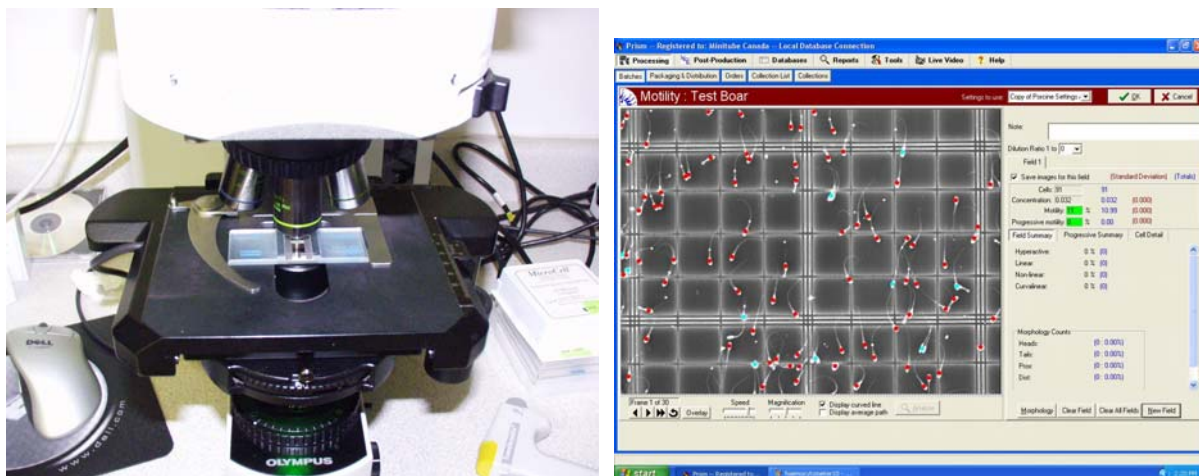
Figure 4. Picture of the improved Neubauer hemacytometer.



Other alternative available for performing this step is by using a CASA system. The SpermVision is capable of calculating the concentration of sperms per mL (Figures 3 and 5) when motility is also evaluated. In the final report of the sample, the CASA analysis gives the total number of cells present per dose of semen.

A great advantage of the SpermVision CASA system is that can also be used in combination with the Hemacytometer for performing sperm dose concentration calculations, and capturing the individual cells with help of the computer to make the respective calculation (Figure 5).

Figure 5. Left: Hemacytometer mounted on a phase contrast microscope stage ready to be used for calculating manually the sperm concentration/mL of a semen dose. Right: Screen obtained when counting sperm concentration in a sample by using both the Sperm Vision CASA system and the hemacytometer.



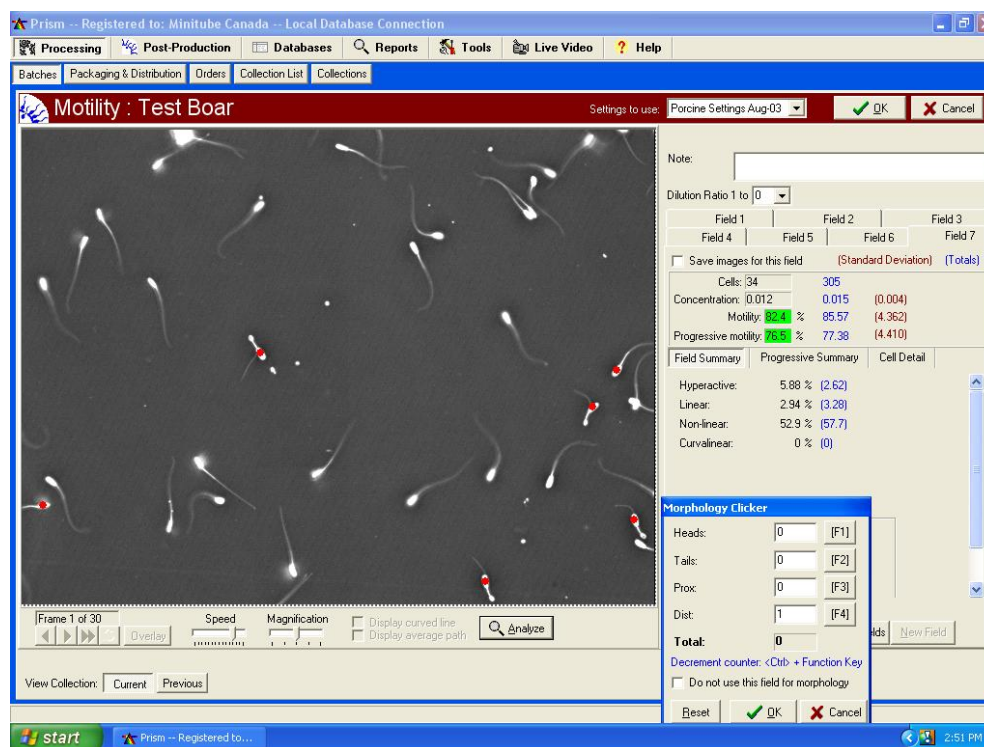
Sperm Morphology Evaluation

1) Gross morphology

This evaluation is performed to have a general idea of the sperm morphology present in the sample analysed and search for any evident sperm abnormality. This method is used especially when several semen ejaculates of different boars have been pooled and extended together (pooled doses). Observation of the sperm morphology is done with a microscope using a low magnification objective (20X) and counting normal and abnormal cells. Defects normally found with this technique are abnormal heads, abnormal tails, cytoplasmic droplets, and detached heads. This type of evaluation does not allow detecting acrosome, DNA, vacuoles, and other sperm morphological abnormalities that require a higher microscopic magnification and staining of the cells.

Gross morphology evaluation can be done with a CASA system such as the SpermVision (Figure 6).

Figure 6. Gross morphology evaluation using the Sperm Vision.



2) Detailed differential morphology

Sperm cells are translucent when observed with bright field microscopy reason to require the use of either special microscopy techniques or sperm staining techniques in order to perform a thorough and detailed morphological evaluation of the sample sperms, especially when reproductive sub-fertility is suspected. When using wet mounts, a drop of extended semen is

placed on a glass slide, the sperm cells are immobilized with a little drop of glutaraldehyde and then a cover slip is placed on top of the semen drop. To evaluate detailed differential sperm morphology in wet mounts, observation at x 1000 magnification under immersion oil is required in combination with specialized microscopic optical techniques such as Phase Contrast or Differential Interference Contrast (DIC) (Barth and Oko, 1989).

An alternative for detailed differential morphology is to make an extended semen smear stained with Eosin-Nigrosin observed at x 1000 magnification under immersion oil using bright or phase contrast microscopy (Figure 7) (Barth and Oko, 1989).

Figure 7. Detailed differential sperm morphology evaluation in a semen sample stained with Eosin-nigrosin observed at x 1000 magnification/oil immersion with bright microscopy.



With any of the techniques described it is necessary to count at least 100 sperm cells per sample which will be classified in morphological categories. The number of categories used will depend on the training received by the evaluator and how confident he/she feels about performing the evaluation. In general, the basic categories used for sperm differential morphology evaluation are normal cells, head defects, tail defects, and cytoplasmic droplets. However the classification can be extended to categories such as acrosome defects, detached heads, midpiece defects, proximal droplets, distal droplets, teratoid cells, other cells present, etc.

SEMEN CULTURE FOR BACTERIOLOGY

Bacteriospermia or contamination of semen with bacteria is a very common finding in collected boar ejaculates (Althouse and Lu, 2005).

Although the boar reproductive tract is free of bacteria, boar ejaculates post-collection are heavily contaminated with bacteria containing 10^2 - 10^6 microorganisms/mL (De Grau et al.,

2006). The primary origin of semen bacterial contamination is the boar, but other contaminant sources contributing are the barn environment, personnel working in the barns and laboratories, and the quality of water used to dilute the semen extender (Althouse and Lu, 2005). The semen contamination normally happens during the collection process due to the proximity of preputial fluids, manure, hair and skin. The hands of the technician performing the collection and equipment used during semen collection, processing and extension play a very important role in contamination (De Grau et al., 2006).

The majority of the bacteria species found as contaminants in boar semen are from the family Enterobacteriaceae. The most popular species of bacteria reported in the literature as contaminants are *Enterococcus* spp (20.5%), *Stenotrophomonas maltophilia* (15.4%), *Alcaligenes xylosoxidans* (10.3%), *Serratia marcescens* (10.3%), *Acinetobacter lwoffii* (7.7%), *Escherichia coli* (6.4%), *Pseudomonas* spp (6.4%) and other species (23.0%) (Althouse and Lu, 2005). In a recent retrospective study (Table 1) regarding bacteria found in boar semen samples collected at 12 boar studs across Canada and submitted to 3 different laboratories, the most common grown isolates were *Pseudomonas* spp (25%), *Acinetobacter* spp (9.7%), *Escherichia coli* (6.4%), *Staphylococcus* spp (6.4%), *Citrobacter* spp (6.4%), and *Shewanella putrefaciens* (3.2%) (De Grau et al., 2006).

Contamination of extended semen with high concentrations of bacteria can produce reduced fertility, lower conception rates and short shelf life of semen doses. Bacteriospermia could reduce semen quality by reducing sperm motility, causing sperm cell death, and damage to the acrosome. Sows inseminated with semen contaminated with bacteria can show vulvar discharges and endometritis. For these reasons it is important to emphasize to the boar stud personnel the need of using hygienic semen collection and processing procedures. Excellent cleaning and disinfection of the laboratory equipment and premises is also required, and the addition of antibiotics to the semen extenders has been implemented to protect the sperm cells (De Grau et al., 2006).

Due to the risk of bacteriospermia, it is ideal that boar studs should request quality control of extended ejaculates to detect contaminant bacteria. Each extended semen sample is streak out on a 5% blood agar culture plate using a microbiology culture loop that will be incubated at 37°C for at least 24 hours to detect any contaminant micro-organism present.

The ideal scenario is to have no micro-organisms growing post-culture (Figure 8) (Reicks, 2003).

If there is growth of bacteria in any extended semen sample (Figure 9), the bacterium species needs to be identified and sensitivity/minimum inhibitory concentration (MIC) testing must be done to determine which antibiotics will be able to control the micro-organism (Reicks, 2003). The identification and antibiotic sensitivity/(MIC) can be done by a specialized veterinary microbiology laboratory such as the Animal Health Laboratory located at the Ontario Veterinary College.

Table 1. Results from 181 semen samples collected at 12 Canadian boar studs submitted to three different diagnostic labs across Canada during 2004 - 2005 (adapted from (De Grau et al., 2006).

Bacterium species	Percentage of isolates	Possible source
ALCALIGINES	3.23	Water
<i>Bacillus</i>	3.23	Tubing/ extending system
<i>Candida guilliermondi</i>	3.23	Skin, feces
<i>Clostridium perfringens</i>	3.23	Environment, feces
<i>Enterobacter cloacae</i>	3.23	Skin, feces
<i>Enterobacter sp</i>	3.23	Skin, feces
<i>Enterococcus</i>	3.23	Feces
<i>Lactobacillus</i>	3.23	Feces
<i>Micrococcus</i>	3.23	Skin, environment
<i>Moraxella</i>	3.23	Skin
<i>Providencia rettgeri</i>	3.23	Feces
<i>Pseudomonas aeruginosa</i>	3.23	Soil, water
<i>Shewanella putrefaciens</i>	3.23	Water, soil
<i>Stenotrophomonas maltophilia</i>	3.23	Water
<i>Citrobacter</i>	6.45	Feces
<i>E coli</i>	6.45	Feces
<i>Staphylococcus sp</i>	6.45	Skin
<i>Acinetobacter</i>	9.68	Water baths/warming box
<i>Pseudomonas sp</i>	25.81	Environment

Figure 8. Blood agar plate (below left) with no bacterial contamination post-incubation at 37° C.



Figure 9. Culture plate (above on right) of an extended semen sample contaminated with different micro-organisms.

Extended semen quality control needs to be also implemented in the boar stud laboratory. It is important that specific laboratory areas in any boar stud could be screened and cultured in a regular basis to monitor the presence of micro-organisms (at least once/month). The areas to be cultured should be those ones getting in contact with semen or extender plus those that are normally warm and moist. Some examples of these areas are the water system, tubing used for transport of water or extender, pipette tips, extender vats, collection cups, incubators, water baths, warming boxes, slide warmers, etc. (Reicks, 2003).

When a bacterium is found and identified in a semen sample, it is sometimes possible to predict the potential source of contamination where it is coming from (Table 1).

Minitube Canada received in 2007 semen samples from several boar studs located across Canada for third party quality control evaluation. Of all the samples received, 449 samples were requested for bacteriology culture to monitor potential micro-organism contamination. Out of these specific 449 samples received, 157 (34.96%) showed contamination by growing 1 or more Colony Forming Units (CFU) of bacteria per plate after using a sterile culture loop with a capacity volume of 10 microliter. Out of the 449 samples, 45 (10.02%) grew ≥ 5 (CFU) of bacteria per plate which represents ≥ 500 bacteria per mL of extended semen. Due to this high level of contamination, these 45 semen samples were sent to the Animal Health Laboratory – Ontario Veterinary College (OVC) for bacterial identification and antibiotic sensitivity. In 38 samples out of the 45 submitted to the OVC laboratory were identified bacterial contaminants. Fifty eight isolations of bacteria species were found in these 38 samples and more than 1 species of bacteria were found in some of these bacteriospermic samples. Table 2 summarizes the species of the bacteria identified and their frequency of isolation.

Table 2. Species of bacteria isolated in 38 samples submitted by Minitube Canada to the Animal Health Laboratory – Ontario Veterinary College due to high level of bacteriospermia.

Bacterium species	Times isolated in 38 positive samples	Frequency of isolation
<i>Klebsiella oxytoca</i>	6	15.79%
<i>Enterobacter agglomerans</i>	1	2.63%
<i>Enterobacter cloacae</i>	3	7.89%
<i>Serratia marcescens</i>	9	23.68%
<i>Acinetobacter</i> spp.	1	2.63%
<i>Klebsiella pneumoniae</i>	7	18.42%
<i>Stenotrophomonas maltophilia</i>	7	18.42%
<i>Stenotrophomonas</i> spp.	3	7.89%
<i>Pseudomonas</i> spp.	16	42.11%
<i>Moraxella</i> spp.	2	5.26%
<i>Proteus mirabilis</i>	1	2.63%
<i>Bacillus</i> spp.	1	2.63%
<i>Streptococcus</i> sp. Alpha hem.	1	2.63%

CONCLUSIONS

Performing regular quality control evaluation of the semen doses produced by a boar stud is an excellent practice that serves to monitor and improve the techniques used by stud personnel to collect, evaluate, process, package, and transport boar semen. At the same time it provides assurance to the sow farmers that the final product received is of excellent quality for their AI programs.

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