Proceedings

of the

3rd LONDON SWINE CONFERENCE

Maintaining Your Competitive Edge

April 9-10, 2003
London, Ontario

ONTARIO PORK

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UNIVERSITY of GUELPH

Proceedings

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LONDON SWINE CONFERENCE

Maintaining Your Competitive Edge

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

April 9th and 10th, 2003
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Proceedings of the London Swine Conference – Maintaing Your Competitive Edge

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CHAIR'S MESSAGE

Welcome to the 3rd Annual London Swine Conference!

The goals of the London Swine Conference are 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. We are fortunate to have attracted a very impressive group of internationally recognized speakers who are certain to stimulate thought and discussion. It is our intention that there will be considerable opportunity for discussion and active participation. We are blessed with a wonderful facility and a manageable number of attendees so that everyone has an opportunity to get their questions answered and their opinions heard.

The theme of this year's conference is "Maintaining your Competitive Edge" and talks will address issues related to health, reproduction, changing production practices and how we can compete on the global market. We sincerely hope that everyone who attends will leave with at least one new piece of information that they will be able to immediately implement and that everyone will take away some inspiration to continue to compete in this demanding industry.

We wish to thank the many volunteers who helped make this event possible. The support from the Ontario Ministry of Agriculture and Food, Ontario Pork, and the University of Guelph was essential for the success of the event. We are also very grateful for the financial support of our many industry sponsors.

Enjoy the Conference!

Bob Friendship
Chair, Steering Committee
2003 London Swine Conference

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HEALTH MANAGEMENT

THE DANISH EXPERIENCE AFTER STOPPING THE USE OF ANTIBIOTIC GROWTH PROMOTERS

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INTRODUCTION

The use of antibiotic growth promoters (AGP's) was definitively stopped in Danish food animal production by January 1st, 2000. This ended a period with increasing focus and discussion on the use of AGP's in relation to food safety. The discussion intensified when the AGP Avoparcin was banned in Denmark in 1995. Bacterial resistance in *Enterococcus faecium* induced by Avoparcin cause cross-resistance to Vancomycin, which is used for treatment of *E. faecium* infections in humans. It was considered likely that Vancomycin resistant *E. faecium* from food animals could enter the food chain, establish in humans, and thereby potentially cause infections, which would not respond to treatment. The actual risk of resistant *E. faecium* from animal reservoirs for human morbidity has not been established. The Danish ban was followed by an EU suspension of Avoparcin in 1997. In 1998, the AGP Virginiamycin was banned in Denmark and in 1999 in all EU member states together with the AGP's Spiramycin, Tylosin and Bacitracin.

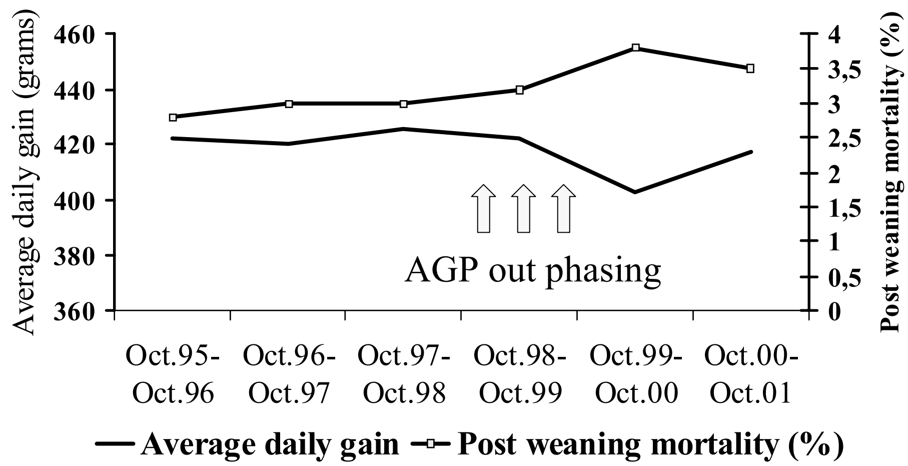
The Danish food animal industries responded to this development by voluntarily stopping the use of AGP's in cattle, poultry and finisher pigs in 1998. During 1999, AGP's were voluntarily stopped in the remaining pig production segments. An EU order to stop the use of remaining antibiotic growth promoter in all member states is expected during the autumn of 2002.

The Danish experience in the pig production sectors has shown benefits as well as drawbacks related to the discontinued use of AGP's.

PRODUCTION AND HEALTH IN WEANER PIGS

Production results from a representative sample of Danish record-keeping herds with weaner and grower pigs (7-30 kg) appear in Figure 1. The sample size varied from 956 to 1816 herds per year. Following the voluntary phasing out of AGP's during 1999, a temporary reduction in growth rate and increase in mortality was observed. Increased prevalence of post weaning diarrhea *(E. coli)* was observed in several herds, but was generally well-controlled by management changes. Proliferative enteritis *(L. intracellularis)* also increased in many herds and is still a major clinical and sub-clinical problem. Oral medication against enteritis in weaners and growers constitutes 80% of the consumption of therapeutic antibiotics for pigs according to Vetstat figures. Vetstat is the national system in Denmark for monitoring the usage of drugs for animals.

Figure 1. Daily weight gain and mortality in weaned pigs (7-30 kg) 1995-2001.

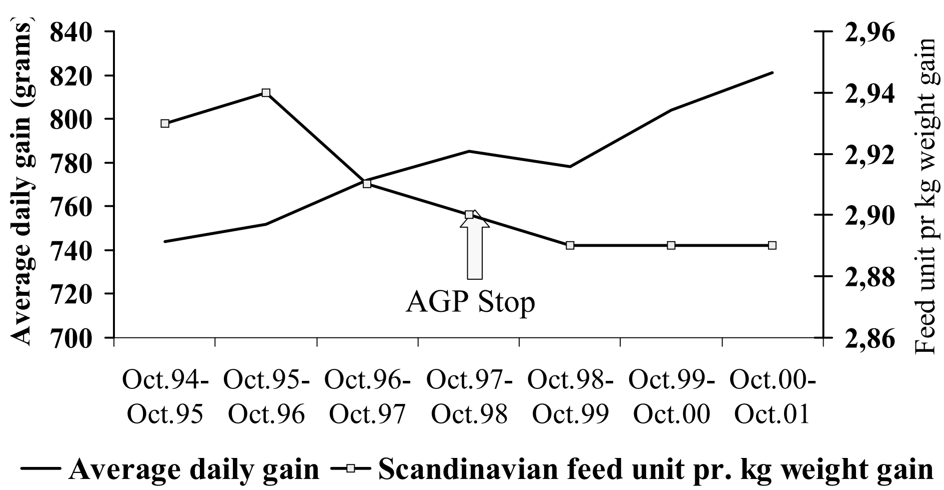


Data: National Committee for Pigs

PRODUCTION AND HEALTH IN FINISHERS

Production results from a representative sample of Danish record-keeping herds with finisher pigs appear in Figure 2. The sample size varied from 956 to 1816 herds per year. Following the voluntary stop of AGP usage in early 1998, a slight and transient reduction in average daily growth rate was observed. No apparent effect was observed in average feed conversion ratio. Some herds experienced increased prevalence of enteritis but generally, the effects in finishers were considered insignificant.

Figure 2. Daily weight gain and feed conversion ratio in finishing pigs (30-100 kg) 1994-2001.

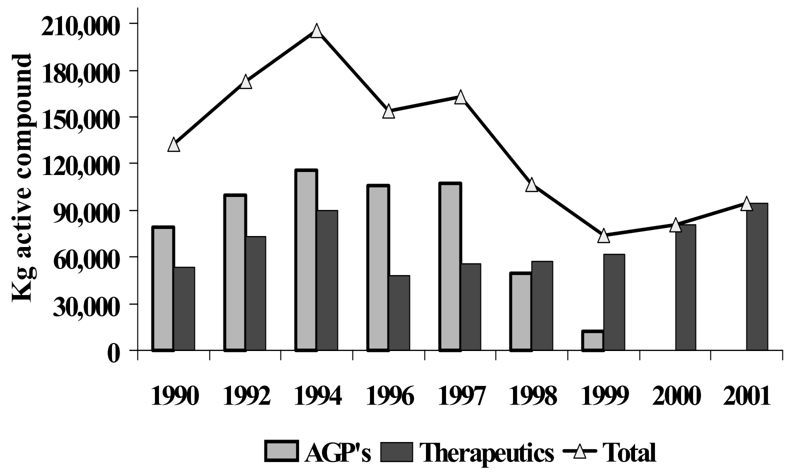


Data: National Committee for Pigs

CONSUMPTION OF ANTIBIOTICS

Following the AGP stop an increased consumption of therapeutic antibiotics was observed (Figure 3). All therapeutic antibiotics for swine herds are prescribed by vets and bought from pharmacies. The increase was mainly due to increased use of oral medication for treatment of enteritis with tetracyclines and macrolides and is not explained by increasing national pig production. However, the total antibiotic consumption (therapeutic + AGP) is considerably lower than before the AGP stop.

Figure 3. Consumption of antimicrobial growth promoters and veterinary therapeutic antimicrobials in Denmark 1990-2001.



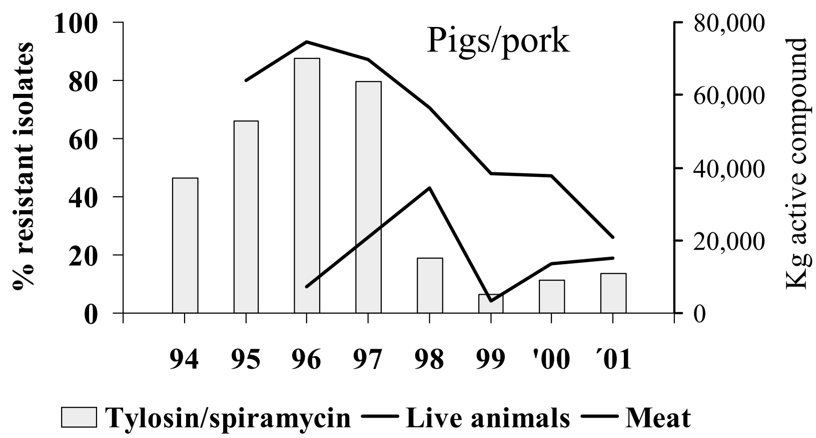
RESISTANCE TO ANTIBIOTIC GROWTH PROMOTERS

A decrease in resistance to the most commonly used AGP's was observed in bacterial isolates from animals and to a lesser extent in isolates from meat products after the AGP stop. Figures from the Danish surveillance of resistance development in animals and humans (DANMAP) are shown in Figure 4. At present no studies showing direct health-related effects in the human population due to the AGP stop have been performed.

EFFECT ON SALMONELLA IN PIG HERDS

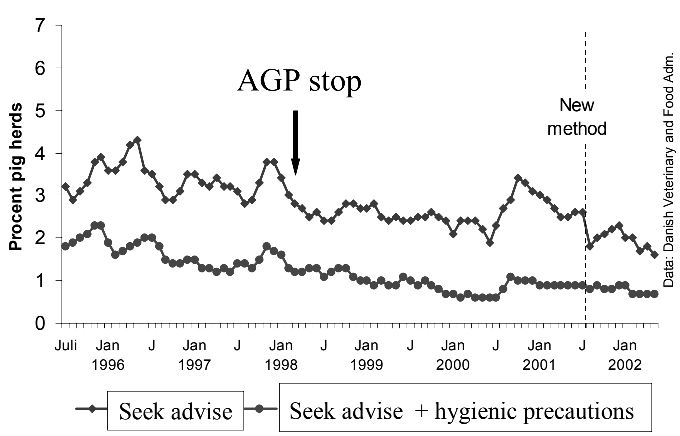
The prevalence of salmonella-infected pig herds has decreased further after the AGP stop. Figure 5 shows the data from the nationwide salmonella surveillance programme based on meat-juice testing for salmonella antibodies from slaughtered pigs. Level 1 herds have no or very low levels of sero-positive animals. Level 2 herds have higher levels and should seek advice. Level 3 herds have high levels and should seek advice and special precautions are carried out at the slaughter plant. Deductions in payment from slaughter plants are made for pigs delivered from level 2 and 3 herds. The cause of the sudden increase in mid-2000 is unknown.

Figure 4. Tylosin/Spiramycin consumption and resistance to Erythromycin among E. faecium.



Data: DANMAP

Figure 5. Salmonella surveillance in Danish finisher herds (1996-2001).



CONCLUSIONS

Experiences during the last two years have shown that a profitable intensive pig production was possible without using AGP's. However, significant effects on health and productivity in weaner pigs have been observed. An increased consumption of therapeutic antibiotics has been observed, and the major challenge for the next years will be a further focus to disease control by prophylactic measures and risk factor reduction as opposed to disease control by medication. When medication is necessary, it should be targeted to diseased animals only e.g. animals transferred to isolated hospital pens.

As expected antibiotic resistance in bacteria of animal origin was reduced in parallel with reduced use of antibiotics. The implication of this reduction for human health needs further studies.

ACKNOWLEDGEMENTS

DVM Hanne Dorthe Emborg and Professor Henrik C. Wegener from the Danish Zoonosis Centre are sincerely thanked for preparing several of the figures.

Data and information have been obtained from:

- Danish Veterinary Laboratory
- Danish Bacon and Meat Council
- Danish Zoonosis Centre

THE WHY'S AND HOW'S OF ELIMINATING CLINICAL SALMONELLA

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ABSTRACT

Salmonella bacteria can be commonly found in the intestinal tracts of many animals including swine. These bacteria in food producing animals are of concern since the organisms may contaminate food products and cause clinical salmonellosis in humans. Salmonella can also cause disease in domestic animals, which is the focus of this paper. Reports of clinical diarrhea and deaths due to Salmonella have increased in recent years. The swine industry must maintain its focus on control and reduction of salmonella to minimize clinical disease and the risk of salmonella in the food chain.

BACKGROUND

Salmonellosis has been a concern in human and animal health for a long time. The main concern is its role in foodborne illness in humans. It can also result in clinical disease in livestock. This paper deals with the clinical disease in pigs as it has been seen recently in some Canadian herds.

Salmonella Facts

Salmonella is the name of the genus of a group of bacteria that can be found everywhere in the world. It can be found in the intestinal tract and other body areas of all vertebrate animals. These bacteria are classified by serotype, some of which are only found in one species of host animal. Salmonella bacteria of these specific serotypes are collectively called host-adapted serotypes. Examples of these are *Salmonella choleraesuis* in pigs and *Salmonella pullorum* in chickens.

More troublesome are some of the members of the more than 2000 non-species adapted salmonella serotypes. These can infect multiple host species, have been implicated in human disease, and are implicated in most food-borne salmonella infections. All serotypes can cause disease, however a small number appear to cause most of the salmonelloses seen in people and pigs. The most common Salmonella serotypes isolated from humans and animals are: *S. typhimurium*, *S. enteriditis*, *S. derby*, *S. infantis*, and *S. heidelberg.*

Salmonella are hardy and ubiquitous in the environment. They can multiply at 7 to 45°C, survive freezing and drying well and thus can survive outside all winter. The bacteria can survive for weeks, months, and even years in suitable organic material. For example, Salmonella has been reported to survive for 8 months in meat-meal fertilizer, and 47 days in manure storage lagoons. Survival is greatly hindered below pH 5.0. The bacterium is inactivated by heat and sunlight, and destroyed by most commonly used disinfectants.

The hardiness of the bacteria is not the only factor to contribute to its widespread presence in the environment. Following infection, animals are not able to rid themselves totally of the organism. A carrier state results that allows the Salmonella to be shed in manure for extended periods of time. For example, one study of *Salmonella typhimurium* infections in pigs showed that the organism could be isolated from the feces daily for the first 10 days post-infection, and then frequently for the next 5 months. Pigs were marketed 4 to 7 months after the initial infection; over 90% were positive for Salmonella in the mesenteric lymph nodes, tonsils, cecum, or feces.

Salmonella typhimurium is primarily an infection of the intestine, producing diarrhea. However, some serotypes are able to enter the bloodstream with ease, especially in stressed or immune-suppressed animals, and create a septicemia where the bacteria moves throughout the body and affects many organs. Affected pigs appear very sick and often die rapidly following the onset of clinical signs.

Salmonella infects animals mainly when the animals have oral exposure to fecal material. Probably most animals ingesting salmonella bacteria do not become visibly sick. Whether a pig becomes ill depends on a number of factors primarily: the amount of bacteria the animal is exposed to, the current state of the gut environment (e.g. pH levels) and stressors that influence the ability of the animal to resist disease.

Treatment Considerations

Treatment for salmonellosis can be problematic for several reasons. Firstly is the high variability in the antibiotic sensitivities among the many serotypes. Usually treatment in pigs involves using antibiotics such as ceftiofur, sulfa-trimethoprim, synthetic broad-spectrum penicillins, gentamycin, neomycin, or apramycin. Isolation of Salmonella early in the course of disease to allow testing for antibiotic sensitivity should be done in all cases. It is common to find resistance to some of the antibiotics that are normally recommended for use.

Another problem encountered in treatment is the apparent range of responses seen, even when testing indicates that the bacteria should be sensitive to the antibiotic used. This may be due to more than one serotype causing the problem. The other types might have a different antibiotic sensitivity pattern than the one isolated and tested. In other cases, the antibiotic appears to be slow in clearing out the problem because treatments may actually increase the level and duration of the carrier state. It has been shown that antibiotic treatment of infected pigs with intestinal salmonellosis did not reduce the duration and magnitude of bacterial shedding in the feces. It is worth noting that uncomplicated intestinal salmonellosis in humans may not be treated with antibiotics. Treatment is directed mainly at supportive therapy to counteract dehydration.

Treatment of the septicemic form of salmonellosis is necessary to prevent death, and to allow a faster and complete recovery. Pigs with septicemia need to be given medication as early as possible in the course of the disease since, with this form, pigs can die rapidly after the onset of signs of illness. In outbreaks, the pigs need to be checked frequently. Usually a broad-spectrum antibiotic is offered in the water to help susceptible pigs in the population deal with the organism early and decrease the chances of the infection progressing to the septicemic form. Culture and drug sensitivity tests are essential.

Control and Prevention Considerations

In an outbreak situation, a pig with diarrhea will massively contaminate its pen environment with bacteria in its feces and this is the single most important source of infection for other pigs. With hot strains where death losses add up quickly, I recommend antibiotic injections of all pigs in the pen, not just the sick ones. Preventive medication will protect the animals from disease symptoms (but not from infection).

Control of an outbreak also involves restriction of animal movement to prevent animals from tracking the bacteria around the barn on feet and skin, or the inadvertent movement of carrier pigs. Also control people movement and ensure that contaminated clothing and equipment that have been in contact with diseased pens do not contact healthy groups. Ensure that the water system is providing a good supply of clean water and that the water nipple flow rate is optimal. Scrape pens of sick pigs frequently but be sure that clothing is changed and hands are washed before going to healthy groups. Scrapers and shovels should be dedicated to pens with sick animals only, and washed and disinfected before using elsewhere.

Can a good biosecurity program prevent salmonellosis? Keeping all Salmonella out of a pig barn (or any group of animals) is a challenge and likely not possible. The organism is ubiquitous in the environment and exposure to one serotype or another is inevitable. Understanding the risk factors for Salmonella infection and disease is important.

Most, but not all, of the serotypes that pigs can encounter in the environment will only cause mild scours or even no signs at all. Others such as *Salmonella typhimurium* that can potentially cause more severe problems are more likely to come onto your farm in the intestines of a pig or any other vertebrate animal. Transportation vehicles, equipment or people from other farms, packing plants, collection yards, auction markets, etc are also high-risk sources.

Certainly a good biosecurity program is important. Good sanitation of pig transport vehicles and personnel is essential. Preventing exposure of pigs and pig feed to other animals and their feces is also important. What about replacement breeding stock, weaners or feeders coming onto the farm? Until recently it has been difficult to screen source herds since negative bacterial cultures did not guarantee that the animals were free of infection. A serological test that will detect antibodies to most Salmonella serotypes in an animal's blood is available. Sampling is still a problem because if a herd is very stable and only a few animals are carriers of the organism, then the chances are lower that they will be sampled and thus detected. Initial surveys should sample at least 30 animals in each stage of production. A higher prevalence of positive animals would be expected in groups that are blood tested in a 2 to 6 week time frame after being moved, mixed, and/or transported.

Thorough sanitation is often given as a key point in prevention and control of Salmonella because it will reduce the level of barn contamination and pig exposure. It is an important factor. But for some of the more virulent serotypes, as discussed above, the level of sanitation needed to reduce the bacteria below the infective level is extraordinary. Salmonella will force us to become very meticulous in the way barns are cleaned.

Another point on control is the ability to help the pig control Salmonella in its own gut. Antibiotics can be effective but are not the solution in the long term. Salmonella bacteria are adept to developing populations with various levels of antimicrobial resistance. And antibiotic use likely promotes the carrier-state in animals.

Much attention is being directed towards the use of other products that make the intestinal tract a less inviting place for Salmonella organisms to grow. In Europe, organic acids, such as propionic or formic acid, are added to the feed or water, or feed is fermented to achieve the same ends. Since Salmonella does not do as well in acidic conditions, especially below pH 5, this reduction in the lower gut pH restricts its growth. Other products attempt to promote the growth of beneficial bacteria that will compete for space and food with the Salmonella, and will also produce organic acids that will reduce gut pH. Probiotics have been tried and have been adopted with some success. Other substances such as bambermycins (Flavomycin®, Intervet Canada Inc.) will alter the normal gut bacteria population and tip the scales against Salmonella. Meal feeds, especially if not too finely ground, also affect gut environment to the detriment of Salmonella.

Vaccines have been developed against some Salmonella serotypes. These include killed injectable products and injectable or oral modified-live vaccines. In pigs the vaccines have been mainly developed for *Salmonella choleraesuis*. This is the specific pig adapted Salmonella which is of low clinical prevalence in Canada today. The modified-live vaccines are reported to cross- protect against several serotypes of Salmonella, and have been used to prevent outbreaks of clinical salmonellosis as well as reduce the prevalence in groups to control food-borne contamination.

CLINICAL CASE

Background

In July 1996, a new 4-room, 2000-head feeder barn had just been filled with 25 kilogram feeder pigs from 6 sow farms each with on-site nurseries. The feeder barn was a fan-ventilated barn with about 30% of the pen floor space slatted. Water and feed were provided in a wet/dry feeder. Water was obtained from a man-made pond on the farm, and feed was a pelleted barley/soybean formulation purchased from a local feed supplier.

The batch of pigs started without any problems. On the seventh day after the fill, the manager found 4 dead pigs in one room during his morning pen checks. They had a slightly reddish skin coloration especially on the belly area. By that afternoon about 25 pigs in 4 pens were noticed to have a watery amber-coloured diarrhea. Four more pigs in the same room died later that day. The next morning 6 more pigs were dead, 5 from the same room and 1 from another room. A clear yellow-tinged diarrhea was seen in 9 of the 24 pens in the room that first had the problem and in 2 pens in the other room. Problems seemed to "cluster" around certain pens in the barn. Diarrheic pigs were lethargic.

Post mortems were performed and intestine, liver, lymph nodes, lungs, spleen and kidney were submitted to the local diagnostic laboratory for culture and sensitivity. Feed samples were submitted for Salmonella isolation.

The pigs were treated with Neomycin (Neomix Soluble Powder®, Pharmacia and Upjohn Animal Health, 125 gm / 678 litres drinking water) in the water and all sick pigs were injected with sulfa-trimethoprim (Borgal®, Intervet Canada Ltd., Dose – 3 ml per 45 Kg BW intramuscularly). By day 6, mortality rose to 52 pigs in the first room and 25 pigs in the other infected room. Interestingly, the problem stayed out of the other two rooms. Once the "hot wave" of infection subsided after about 10 days, there was no recurrence of problems and the batch went on to finish out normally. Overall, mortality from the outbreak was 3.9%.

The laboratory isolated Salmonella from intestines and, in some pigs, they also found it in other tissues such as lung and kidney. It was later typed as *Salmonella typhimurium* Phage types 104 and 108. No Salmonella was found in the feed samples.

But the story isn't finished. The barn was completely emptied, and it, and all equipment, was cold water washed – no detergent - and disinfected thoroughly. The next group was brought in (same sourcing as the first batch) and the same outbreak of the characteristic clear yellow diarrhea occurred. It affected about 20/96 pens in the barn. The manager started the group on neomycin in the water immediately and mortality was contained to 26 animals or 1.3% of the batch. At the end of that batch, the barns were washed and disinfected more thoroughly, the pits were cleaned and disinfected, and water lines were pulse disinfected with chlorine. Source herds were examined for any evidence of salmonellosis and laboratory cultures of random fecal and pen sampling did not pick up any Salmonella. The feeder pig trailer was swabbed after the routine washing and before transporting the feeder pigs to the barn and no Salmonella was cultured. The barn was filled and within two weeks the same thing happened but again less severe than in the previous batch. This problem continued for two more batches, each time less prevalent and severe than the previous time.

Breaking the Disease Cycle

The barn manager was able to detect the presence of pigs with Salmonella enteritis very quickly and would inject the entire pen with a sulfa-trimethoprim product. This approach would contain the problem to a small number of pens in the barn. An internal biosecurity program was started where boots were changed between rooms and one pair of boots was designated to be worn only in pens with pigs being treated for Salmonella enteritis. Between uses, the boots were stored in a disinfectant bath. The barn was cleaned and disinfected in a normal manner and then various areas were swabbed to detect any Salmonella present. Table 1 indicates where Salmonella was found. A more thorough cleaning was done with hot water and with special attention to feeders and areas of dust accumulation. Routine chlorination of drinking water was started. A more thorough rodent control program was initiated. From that batch to the present no Salmonella problems have been seen clinically.

Table 1. Salmonella typhimurium isolations.

Area Tested	Number Positive/Number Tested
Dust of feed lines	3/6
Dust in re-circulation box	1/6
Feeder tray	2/8
Solid floor	0/8
Slat top	0/8
Slat side	2/8
Pit slurry	0/6
Concrete back wall	0/6
Mice	2/6

Questions and Discussion

A few questions remain about this disease outbreak.

Where did the Salmonella come from? Did it arrive in the purchased feeder pigs? There were about a dozen other feeder barns that were taking pigs from the same sow sources that did not experience any clinical problems from Salmonella. A random sampling of pigs in the source herd nurseries did not pick up Salmonella.

Did they pick it up from contaminated transportation? The delivery trailers were used only for feeder pig delivery within this network of pig producers. Other barns filled from pigs transported on these trailers did not break with Salmonella.

Did the Salmonella arrive on that farm through other sources? Did people or wild animals track it in? Was it brought to the farm in the intestinal tract of birds, rodents or other animals? During the construction phase there was free access to the building by all.

Was contaminated feed the source? Possibly, but no Salmonella was isolated in this case. No clinical Salmonella was seen in other herds that I service that purchased feed from that mill. North American and Danish surveys indicate that *Salmonella typhimurium* is not commonly found as a contaminant in swine feed.

The problem with verifying a likely source of infection is the ability of all Salmonella to live in low numbers in the intestines of healthy animals. Manure sampling could turn up negative results even on infected carrier animals. This is due to both the sensitivity of the sampling and the testing procedure, which might be too low to detect a low number of organisms present. Moreover, chronic carrier animals will shed Salmonella in their feces only sporadically. When trying to find the bacteria in the environment or feed, low grade levels probably would not be detected because the number of samples needed for detection would be higher than the number that are often taken in barn checks.

Once on the farm, where does Salmonella survive between all-in-all-out batches of pigs? The Salmonella remained on farm in spite of more stringent washing and disinfection. It was not until our investigation showed that this manure-borne organism was found in areas other than floors, slats and pits, that a more thorough reduction of the Salmonella in the barn environment could be accomplished. And what was the role of rodents as a reservoir for the disease organism? My colleagues in the poultry industry have told me that in some barns, rodent control was the turning point in Salmonella reduction programs. A study showed that mice can shed up to 230,000 Salmonella per fecal pellet. It takes as few as 10,000 Salmonella of some serotypes to clinically infect a healthy pig.

What allows the Salmonella to become a clinical problem? Were the animals challenged with a high level of Salmonella? Usually we would associate these problems with unsanitary conditions where the level of Salmonella in the environment is high. This barn was very clean. The pigs dunging pattern was normal and any manure accumulations were scraped away daily. It did not appear likely that a large Salmonella build up caused the problem. One study in chickens indicated that Salmonella could be transmitted through the air. It also indicated that the dose of infective bacteria required to cause disease was less when infection came via the air than via oral exposure. This was dependent on the virulence of the organism. Our barn check showed Salmonella in dust in recirculation ducts and on feed lines (Table 1). This is most likely dust from dried feces and may present another route of Salmonella spread in the barn.

Was it a factor of virulence? Some serotypes of Salmonella require a very small dose of bacteria to create disease in healthy non-stressed pigs (as few as 10,000 organisms compared to a normal infective dose of 100,000,000 bacteria).

Were the pigs in a period where they were more susceptible to infection and the clinical disease? Stressors that suppress the animals' immune system such as transportation, and mixing, are known to allow healthy Salmonella carriers to start shedding the bacteria in large numbers in their manure. The same stressors increase the pig's susceptibility to a disease. Also a change in feed or water, or antimicrobial use can alter the normal balance of bacteria in the gut and perhaps would allow Salmonella to colonize and increase in numbers to a clinical disease threshold level.

CONCLUSIONS

Salmonella infections will continue to be a topic of concern in the swine industry due to its potential to create clinical disease on-farm and because of its role in foodborne infections in humans. Future quality assurance initiatives at the farm level will bring focus to on-farm practices in the control of Salmonella and other potential foodborne pathogens. Total elimination of Salmonella bacteria in a barn is not feasible due to the world-wide prevalence and persistent nature of the bacteria. Reduction and control of the organism is possible through a planned approach involving sanitation and biosecurity plans, and when needed, other tools such as nutritional changes to modify gut environment.

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KEY PRINCIPLES OF BIOSECURITY

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ABSTRACT

The goal of our research program is to put science into biosecurity protocols. We realize that bigger issues such as siting, pig proximity, and aerosol transmission offer risks that we cannot control in many cases. Thus, our research has focused on the details within production units that we can control - specifically the role of people as mechanical vectors in transmitting porcine pathogens. These details are important because we most likely track pathogens among groups of pigs before we observe the clinical signs of an outbreak.

INTRODUCTION

Biosecurity and sanitation practices are implemented on many pork production units to prevent the introduction of pathogens to the herd or to groups of pigs within the herd. These protocols must take into consideration a multitude of risks for pathogen introduction. Many decisions regarding biosecurity protocols on pork production units are currently based on producer and veterinary experience and opinion, not on scientific research. Not knowing the extent to which biosecurity measures need to be implemented to prevent the transmission of porcine pathogens is an important problem, because, until that information is known, pork producers will run one of two risks:

- Expenditure of time and money on unnecessary biosecurity measures, or
- Insufficient biosecurity measures that place the pig population at risk for economically devastating disease outbreaks.

The argument often presented is that all biosecurity measures, even if not effective, are important because implementation of biosecurity protocols sensitizes personnel to biosecurity issues. The biosecurity mind-set of the personnel is thought to enable workers to pay more attention to details that, if performed sloppily, might place the herd at risk of infection. I wholeheartedly agree that we must encourage our colleagues to pay attention to these details in their work. As most biosecurity procedures have not been validated, we must do the best we can with the information that we have to date. However, I feel that a dangerous premise is set when we recommend procedures that have been scientifically shown to be ineffective, just to give the 'perception' that we are doing everything possible to prevent breaches in biosecurity. Encouraging people to perform biosecurity tasks that are known to be worthless damages our credibility. One would not ask personnel to vaccinate a herd for pseudorabies using a modified live vaccine that had been mixed and then stored for 2 weeks at 90°F just to give the perception that by vaccinating the pigs, they were doing everything possible to prevent an outbreak of pseudorabies. Eventually, employees and clients will recognize the hoax and your future recommendations will not be heard.

BOOT BATHS

Farm personnel use boot baths with the goal of preventing mechanical transmission of pathogens among groups of pigs. However, in the authors' experience, boot bath maintenance on most facilities is poor, and frequently boot baths are grossly contaminated with organic matter. People commonly avoid stepping into boot baths or simply step through the bath without stopping to clean their boots.

Literature on boot bath use is scarce and usually limited to the authors' opinions on proper procedure. Phenolic detergents have been recommended for use in boot baths (Quinn, 1991). Effective utilization of boot baths consisted of cleaning boots in a preliminary bath filled with dilute detergent, followed by immersion of clean boots to a depth of 15 cm, for at least 1 minute, in a second bath filled with detergent. The author advocated that large units prepare new boot baths daily or when visibly contaminated and small units prepare new boot baths every 3 days (Quinn, 1991).

We recently evaluated Cidex Formula 7*, Nolvasan®, Chlorox®, Betadine Solution, 1Stroke Environ®, Roccal-D Plus, and Virkon®S utilizing various boot bath protocols (Amass *et al.*, 2000; Amass *et al.*, 2001). Basic principles of proper boot bath use learned from these experiments include:

- Scrubbing visible manure from boots enhances removal of significant numbers of bacteria. Simply walking through a boot bath will not reduce bacterial counts. Standing in a boot bath for up to 2 minutes without scrubbing off the manure did not significantly reduce bacterial counts except when a cost-prohibitive disinfectant (Cidex formula 7*) was used.
- Scrubbing visible manure off in a water bath is as efficacious as scrubbing manure off in a bath of the disinfectants tested as far as reducing bacterial counts. Although not tested, detergents may make manure removal easier.
- Scrubbing off manure in a clean disinfectant boot bath (1Stroke Environ®) reduces the bacterial count more than scrubbing boots in a contaminated boot bath.
- Boots that have been scrubbed free of manure and then soaked in Roccal-D Plus for 5 or more minutes meet the standard for disinfection.
- Boots that have been scrubbed free of manure and then dipped in Virkon®S meet the standard for disinfection the majority of the time.
- Boots that have been scrubbed in Virkon®S for 30 seconds meet the standard for disinfection; however, a clean tub of Virkon®S must be used each time.

Time constraints make proper use of boot baths within production units difficult. However, spending time and money to implement boot bath procedures on a farm without using them correctly is a waste of resources. Although going through the motions of stepping in a boot bath has benefits of increasing employee awareness of biosecurity and maintaining a clean workplace, this insufficient biosecurity measure as tested in this study may place the pigs at risk for infection because contaminated boots are being used by personnel.

In conclusion, boot stations with hoses and brushes will facilitate manure removal. Disinfectants should be selected based on efficacy, cost, ease of use, and environmental friendliness. Manure should be removed from boots before placing them in a boot bath or else a new clean boot bath needs to be prepared each time boots are cleaned. The intention of this research was not to have everyone stop cleaning boots, but instead, to encourage the use of effective footwear cleaning protocols.

PEOPLE

People-flow into and within production units comprises a large component of biosecurity; however little research is available to support common policies regarding people movement. Sellers *et al.* (1970), sampled people who had contacted animals infected with FMDV. More FMDV was isolated from the nose than the mouth of these people. Virus was isolated from the nose of one person at 28 hours, but was not isolated after 48 hours. Nose blowing or washing was not effective in eliminating the virus, and cloth or industrial masks were not effective in preventing inhalation of the virus. Transfer of the virus between people was documented after persons in contact with infected animals spoke to unexposed colleagues in a box for 4 minutes. One year later, Sellers *et al.* (1971) reported that FMDV could be transferred by human beings, from infected pigs, to susceptible cattle. Results from Seller's work appear to be the origin for the "48 hour rule" used by many producers even though different viruses and bacteria may be harbored for longer or shorter periods by humans. Wentworth *et al.* (1997) recorded transmission of SIV to human caretakers. In this study, pig-to-human transmission occurred despite the use of Animal Biosafety Level 3 containment practice (coveralls, boots, goggles, gloves, hairnets, and dust masks).

In contrast, Goodwin (1985) reported that the culture of breath and hair samples from a person exposed to pigs experimentally infected with *M. hyopneumoniae* did not result in reisolation of *M. hyopneumoniae*. Additionally, we could not detect pig-to-human transmission of *S. suis* using throat swab samples collected from farm personnel who were working in close daily contact with infected pigs (Amass *et al.*, 1998).

Our investigations (Amass *et al.*, 2000) of people as mechanical vectors for PRRSV were less conclusive. Although people did not transmit PRRSV from pigs with acute PRRS to uninfected pigs under the conditions of our study, there was some evidence that people could be contaminated with PRRS viral RNA after contact with infected pigs. PRRS viral RNA was detected in saliva and fingernail rinse samples of 2 of 10 people immediately after exposure to PRRSV-inoculated pigs, on a third person (fingernail rinse) at 5 hours, and a fourth person (nasal swab) at 48 hours after exposure to infected pigs. Further studies should address these findings using virus isolation instead of nRT-PCR to determine if the PRRSV RNA found on people is infectious.

Our studies of people as mechanical vectors of TGEV demonstrated that people could act as mechanical vectors and spread TGEV to healthy pigs; however, handwashing and changing outerwear after exposure to infected pigs was sufficient to prevent transmission (Alvarez *et al.*, 2001).

Thus, it would appear that the risk of transmitting diseases back-and-forth between human beings and swine varies with the pathogen. Quantification of the risk of transmission of common porcine pathogens and individual strains of these pathogens on an individual basis is essential.

CONCLUSIONS

Further research is needed to validate biosecurity methods used in pork production. Once effective biosecurity procedures are defined, producers and veterinarians can develop protocols for production units commensurate with the greatest risks for that farm, keeping in mind that removal of visible manure is central to all biosecurity efforts whether the contaminated surface is a boot, clothing, truck or skin.

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MANAGING REPRODUCTION

THE ROLE OF FEEDING AND MANAGEMENT IN ENHANCING SOW REPRODUCTIVE POTENTIAL

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ABSTRACT

This paper reports on the role that nutrition and management may play in enhancing reproductive performance of the modern sow. Consideration is given not only to energy and amino acid needs, but also to the mineral nutrition of the sow. Practical guidelines are provided to ensure that the correct target body condition at first mating is achieved and that the nutritional needs are met during gestation and lactation. Ways to enhance appetite during lactation are suggested. The overall objective is to ensure that, as far as is possible, the sows achieve a good level of performance on all farms.

INTRODUCTION

Nutrition and management are key components that ensure the modern sow achieves her genetic potential for reproduction. In practice, the actual level of performance is well below the animal's capability and on many farms the norm is 20-22 piglets reared per sow per year, compared with the often quoted potential of 30 piglets per sow per year. Perhaps a more appropriate measure of reproductive performance is the number of piglets produced per sow lifetime, rather than per year, and target levels of 50-60 have been suggested. However, few sows achieve this and 30-40 piglets per sow lifetime is the norm on many farms.

Production targets for ‘good’ and ‘excellent’ levels of performance are suggested in Table 1. Approximately 10% of producers in many countries achieve excellent levels of performance; so why not more? The questions are: how can productivity be increased; how can losses be reduced and can nutrition and management be improved to increase productivity to acceptable levels? A number of factors that may help to achieve this are discussed in this article.

IMPROVING PRODUCTIVITY (OR REDUCING LOSSES)

To increase productivity it is important to know:

- What are the components of litter size?
- Where do losses occur?
- How can these be manipulated through nutritional and management practices?

Analysis of the results of several herd recording schemes, such as that of the Meat and Livestock Commission (MLC) in the UK (MLC, 1995-2002), would suggest that the major difference between the bottom- and top-producing herds is the number of piglets born and born alive, as well as the number of litters produced per sow per year (Table 2). Interestingly, the difference between the total number of piglets born and those weaned, was similar across all herds, regardless of the level of productivity. This perhaps suggests that, in order to improve performance, there must be an increase in either ovulation and/or fertilisation rate and a decrease in embryo losses, as well as knowledge of those factors that influence them. Similarly, in order to increase the number of litters per sow per year, there must be a reduction in the period between weaning and mating, as well as a reduction in the number of sows that return to oestrus.

Table 1. Production targets for the modern sow.

	Good	Excellent
Sow replacement rate (%)	40	35
Farrowing rate (%)	85	90
Litters / sow / year	2.3	2.4
Empty days * / year	<35	<20
Piglets born alive / litter	11.3	12.5
Piglets weaned / litter	10.2	11.3
Piglets reared / sow / year	23.5	27.0
Piglet weight at weaning ** (kg)	7.0	7.0
Litter weaning weight (kg)	71	77
Sow feed consumed / piglet weaned (kg)	50	50
Litters per sow lifetime	4	5

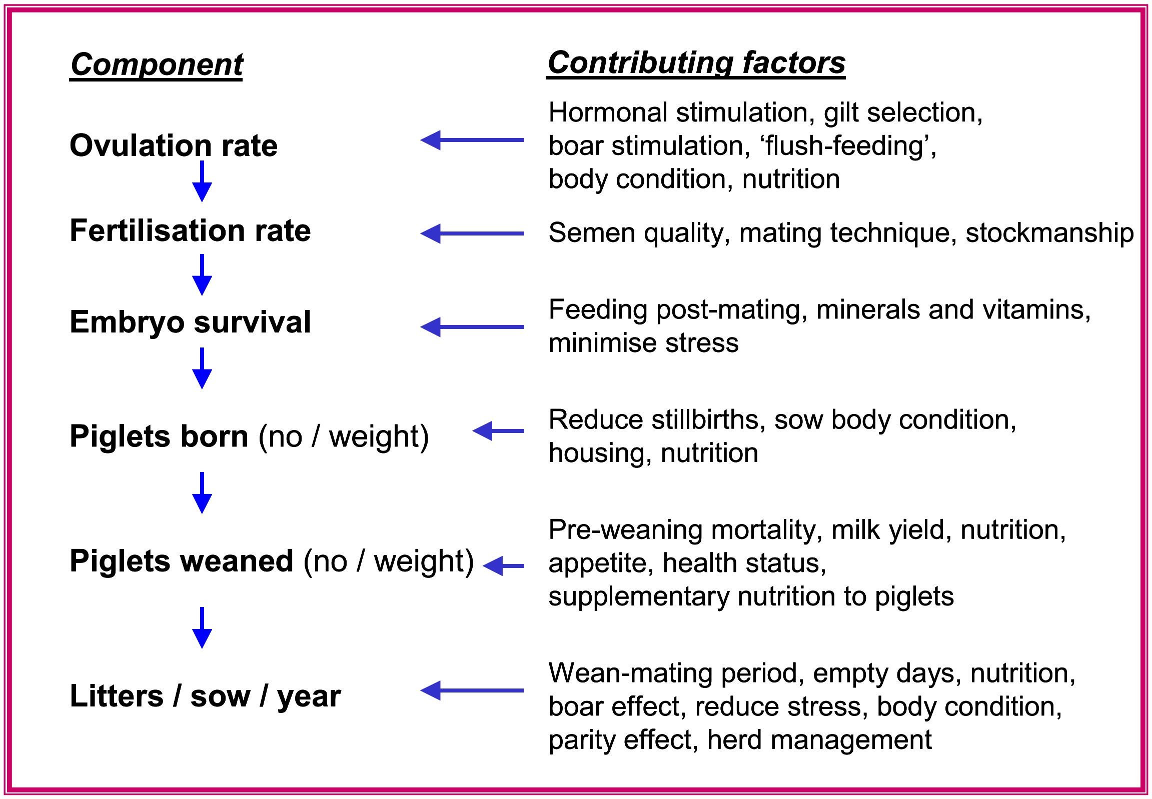
** A 7-day weaning – mating period has been allowed*
*** Piglets weaned at 23 days of age*

Table 2. Litter size in herds of varying productivity (MLC, 1995-2002).

	Bottom 1/3	Average	Top 1/3	Top 10 %
Piglets				
Total born	11.4	11.9	12.3	12.7
Born alive	10.5	11.0	11.4	11.8
Weaned	9.3	9.8	10.2	10.6
Sows				
Litters / sow / year	2.12	2.25	2.34	2.41
Piglets / sow / year	19.7	22.0	23.9	25.6
Non-productive days	53	37	26	13

If improvements are to be made and potential losses reduced, it is important to understand how the different components of litter size impact on reproductive performance and the major factors that influence them. These are outlined in Figure 1, demonstrating the importance of both nutrition and management.

Figure 1. Components of litter size in pigs, and contributing factors.



GILT CONDITION AND MANAGEMENT

The body condition of the gilt at first mating has a significant effect on sow lifetime performance. Animals that do not have sufficient body condition when first selected and introduced on to the farm generally fail to achieve a reasonable number of parities. The better the body condition, the better the lifetime performance of the animal (Gueblez *et al.*,1985; Gaughan *et.al*, 1995; Challinor *et al.*, 1996). The gilt must therefore be sufficiently mature, of appropriate body condition and have adequate reserves of lean and fat in her body. The latter is necessary not only to initiate the reproductive processes *per se*, but also to act as a buffer in times of nutritional inadequacy, when metabolic needs exceed nutrient intake. In addition, body reserves are also needed to protect the animal in poor environmental circumstances.

The young gilt should therefore be of sufficient age, size, maturity and achieve a certain target body condition at first mating. Suggested guidelines are:

- 220 - 230 days of age.
- 130 - 140 kg body weight.
- 16 - 20 mm P_2 backfat thickness.
- Mating at 2^{nd} or 3^{rd} oestrus.

To achieve these, it is suggested that the young breeding gilt be selected at ~60 kg body weight and put on a special gilt rearer diet and feeding regime, as indicated in Table 3. The best practical strategy to ensure maximum ovulation rate and embryo survival in gilts is to provide a high feeding level for the oestrus cycle before mating, that is flush feeding, followed by a low feeding level for the first 21 days post-mating (Ashworth and Pickard, 1998).

The gilt rearer diet should not only contain the correct level of energy and amino acids, but should also be fortified with specific minerals and vitamin that help to stimulate reproduction *per se* and ensure the strong bones and legs that are vital for a long breeding life. Culling because of leg and foot problems is common on many farms.

Table 3. Phased feeding regime for gilts.*

	Body weight (kg)	Age (days)	Backfat thickness (P_2 mm)	Mcal DE	Lysine (g)	Feeding strategy
				per kg diet		(kg/d)
Phase 1	25 - 60	60 - 100	- 7	3.25	12.0	*ad-libitum*
Phase 2	60 - 125	100 - 210	7 - 16	3.10	8.0	2.5 - 3.5
Phase 3	125 - 140	210 - 230	16 - 18	3.10	8.0	*ad-libitum*
Phase 4	early gestation	230 - 260		3.10	8.0	2.0

* These are suggested values. Body weight and backfat thickness may vary slightly, depending on genotype and environmental circumstances.

NUTRITION DURING GESTATION AND LACTATION

Designing a feeding and management strategy requires knowledge of the nutrient needs at all stages of the reproductive cycle. Tables 4 and 5 show the energy and lysine requirements of the sow during gestation and lactation. With this knowledge, diets can be formulated and feeding strategies implemented that take account of the individual needs of the animal at each stage of its reproductive cycle and in each type of production system. This is especially important for the modern hyper-prolific sow, where the aim should be to maintain body condition throughout her reproductive life.

During pregnancy, the objective should be to feed the sow a good quality gestation diet for a specified target body weight gain and increase in backfat thickness and to achieve a body condition score of 3.5 at parturition (scale 1-5). These targets change with parity and hence, so will the nutrient requirements, as shown in Table 4. However, the requirements increase as pregnancy progresses, especially in the last trimester of gestation when the nutrient demands of the rapidly-growing foetuses are high. This is illustrated for a gilt during its first gestation (Figure 2). It is therefore important to increase feed intake during this period to ensure a high rate of foetal growth, to maintain the sow in good body condition and to promote the proper development of the mammary glands, which are essential for good colostrum and milk production.

Table 4. **Energy and lysine requirements of the sow during gestation (Close and Cole, 2000).**

Body weight at mating (kg)	Net weight gain* (kg)	Energy (Mcal ME/day)	Lysine (g/day)	Feed (kg/day)
120	45	6.8	15.8	2.25
150	35	7.2	13.8	2.4
200	25	7.6	12.0	2.55
250	15	8.0	10.5	2.7
300	10	8.7	10.0	2.9

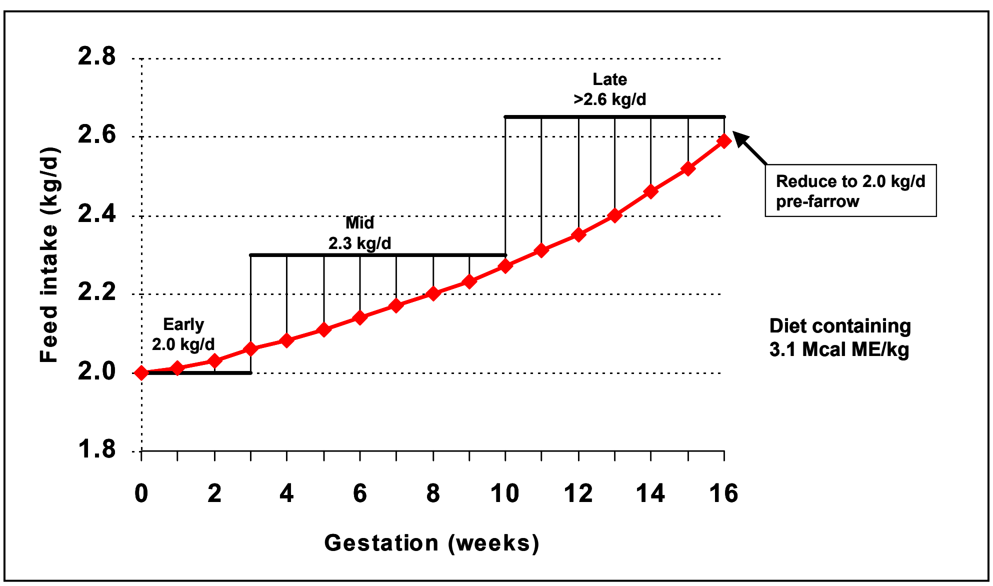
* Excludes growth of gravid uterus and mammary glands. Feed contains 3.0 Mcal ME/kg.

Table 5. **Nutrient requirements during lactation (Close and Cole, 2000).**

Body weight after farrowing (kg)	Energy (Mcal ME/day)		Lysine (g/day)		Feed (kg/day)	
	10 piglets	12 piglets	10 piglets	12 piglets	10 piglets	12 piglets
150	18.8	21.6	49.0	58.0	5.8	6.6
200	20.0	22.8	50.0	59.0	6.2	7.0
250	21.0	23.8	51.0	60.0	6.5	7.3
300	22.1	25.0	52.0	61.5	6.8	7.7

* Feed containing 3.25 Mcal ME/kg

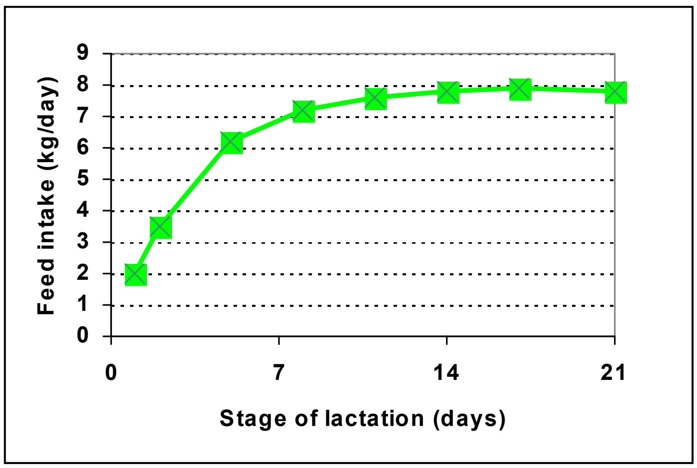
Figure 2. **Feed requirements during gestation (parity 1).**



During lactation, the objective should be to wean at least 10 piglets of good body weight, with minimal loss of body weight and body condition of the sow. Lactation is perhaps the most critical period in the life of the pig and the nutritional strategies implemented in this period influence both the growth and development of the piglets through to slaughter, as well as the subsequent reproductive potential of the sow and overall productivity.

The major objective of nutrition in lactation is to meet the requirement for milk production of the sow, which increases from about 3-4 L/day just after farrowing to 10-12 L/day in peak lactation. Indeed, the values presented in Table 5 are mean values throughout lactation, which do not reflect the increasing needs of the sow as the litter grows and hence milk yield increases. To match this increasing nutritional need, feed intake should be increased gradually during the first 4-5 days of lactation until the sow is consuming 4-5 kg/day when she should be fed to appetite (Figure 3). It is a good idea to provide a lactation feeding scale for sows of different parities and litter size and to have this on hand for each sow in the farrowing house.

Figure 3. Feed requirements during lactation.



200 kg sow at farrowing: 10 kg weight loss during lactation
Litter size: 10 piglets; piglet weight at 21 days: 7 kg

To achieve adequate intakes in lactation, it is important to use good quality diets and soundly-based feeding strategies. Some practical aids to achieving good feed intakes in lactation are listed in Table 6. It may be necessary to feed several times per day, as a sow fed only twice per day may not be able to consume sufficient nutrients to meet metabolic demands, especially in late lactation. On the other hand, it is important not to over-feed in early lactation, as this may limit the animal's voluntary feed intake in later lactation when the needs are greatest; it may also predispose the sow to MMA.

Table 6. Practical aids to enhance appetite.

- Feed a palatable, nutritious feed
- Feed a well-balanced ration of the appropriate nutrient specification
- Gradually increase daily intake over the first week, thereafter feed *ad libitum*
- Feed must be fresh, not stale or dirty
- Feed several times per day, or to appetite
- Pelleted feed is better than meal
- Ensure that fresh water is freely available at all times (consider wet-feeding)
- If nipple drinkers are provided, water flow rate must be >2 litres/minute
- Avoid exposing sow to high temperatures (<20°C) and reduce environmental stress
- Maintain good climatic control in farrowing house
- Do not overfeed in pregnancy
- Increase gut capacity by feeding high levels of soluble fibre in pregnancy diet
- Separate gestation and lactation diets are essential
- Ensure adequate feeding space
- Improve nutrient availability of diet
- Provide supplementary nutrition to piglets
- Reduce metabolic demand by cross-fostering or forward weaning
- Ensure good welfare and well-being of sow

A major limitation to achieving a good appetite during lactation is lack of water and water must always be provided in adequate quantities. If nipple drinkers are provided, then the flow rate must be at least 2 litres per minute. Large sows suckling large litters may need to consume 40-50 litres/day, especially under hot conditions. A lack of water restricts both the feed intake of the sow and her milk yield.

Post-weaning sows should be maintained on high intakes of the lactation ration to prompt a quick return to oestrus and maximise subsequent litter size. Reducing the number of expensive 'empty' or non-productive days will mean more litters per sow per year.

A 3/5-diet feeding strategy best meets the changing nutritional and metabolic needs of the modern, hyperprolific sow and this helps to ensure optimum productivity of the sow and her offspring.

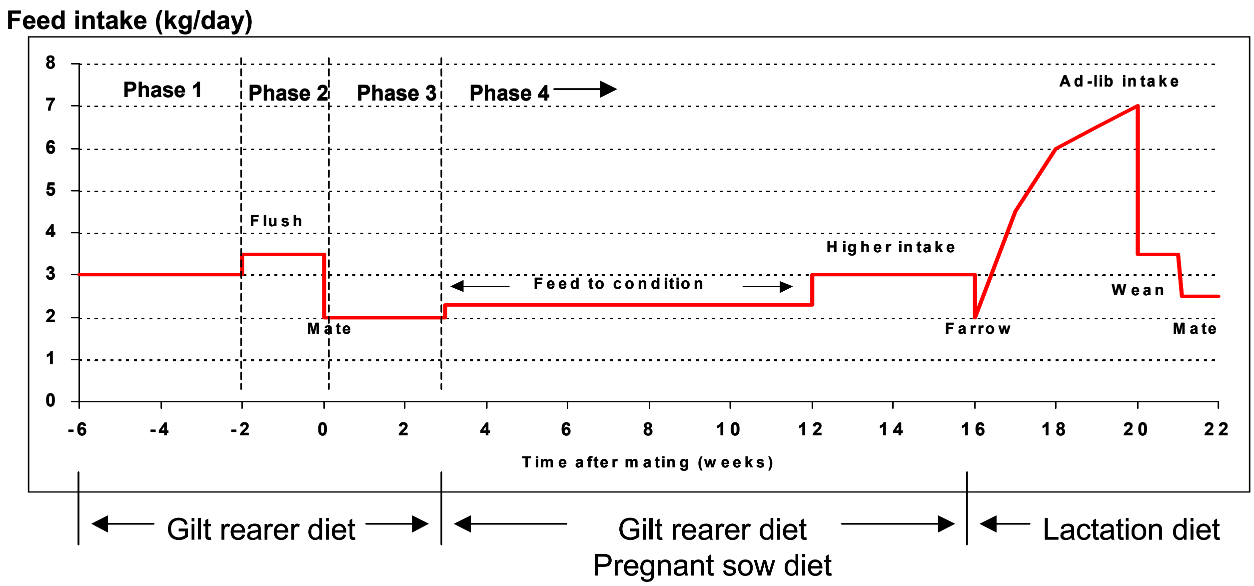
The following dietary specifications are therefore suggested:

Gilt rearer:	3.1 Mcal ME and	8.0 g lysine/kg
Pregnancy:	3.0 Mcal ME and	5.5 - 6.0 g lysine/kg
Lactation (general):	3.25 Mcal ME and	10 g lysine/kg
Lactation (gilts: low intake):	3.35 Mcal ME and	11 g lysine/kg
Lactation (sows: high intake):	3.10 Mcal ME and	9 g lysine/kg

As the lysine content of the diet is known, it is possible to calculate the content of other essential amino acids according to the concept of the 'ideal protein'.

A simple practical feeding strategy that best meets the requirements of the sow at all stages of pregnancy and lactation is illustrated in Figure 4. The feeding levels shown apply to gilts in parity 1; for older sows, feed intake in each subsequent pregnancy should therefore be increased by 0.2 kg/day, depending upon body condition.

Figure 4. Suggested feeding strategy for the modern sow (first parity).



FEEDING TO REDUCE PIGLET LOSSES

From a practical perspective, it is difficult to suggest ways to reduce embryo mortality, other than through good nutrition and management. Some pre-weaning mortality will be associated with overlaying by the sow in early lactation and hence the design of the farrowing crate is important. A good quality gestation sow diet should be fed and feeding levels adjusted to ensure a sow body condition score of 3.5 (scale 1-5). This also helps to ensure that mean piglet birth weight is adequate and above 1.35 kg. Such piglets have sufficient body reserves and vitality to escape overlying by the sow and hence have a high chance of survival. However, on many farms too many piglets are born dead (stillborn) or die during lactation. This increases with the age of the sow and of course affects the number of piglets weaned and hence overall sow productivity.

There is evidence that vitamins and trace minerals, and especially organic trace minerals, may help reduce losses. For example, supplementing the diet with a selenium yeast instead of the inorganic sodium selenite helps to enhance muscle tone of the sow, thus facilitating parturition and reducing stillbirths. The level of Se in milk was also increased (Mahan 2000). This enhances the immune system of the piglet and hence reduces pre-weaning mortality, as well as increasing the weaning weight of the piglet (Janyk *et.al.*, 1998).

Iron is another important trace element, as piglets are born anaemic and must be given supplementary iron after birth, generally in the form of an iron injection. However, adding organic iron to the diet of the sow during gestation and lactation has been shown to increase the iron reserves of the piglet (Ashmead and Graff, 1982; Egeli *et.al.*, 1998), giving it better suckling ability (Close, 1999a). This results in higher colostrum and milk intake, as well as providing a greater stimulus to the sow to produce milk. Pre-weaning mortality is reduced and weaning weight increased. Thus, providing the correct level and source of trace minerals may help to reduce losses.

Low milk yield of the sow results in inadequate nourishment of the piglets and poorer immune status; they become more susceptible to stress and disease. Sauber *et al.* (1999), have shown that the lower the health status, the lower the feed intake and milk yield of the sow and the poorer the performance of the piglets. Thus, measures that improve the appetite and health status of the sow and boost her and her piglets' immune status are very important.

When the appetite of the sow is low, especially under hot conditions, it is important to provide supplementary nutrition to the piglets to ensure that they grow at a good rate during lactation and reach an acceptable body weight at weaning. Azain *et.al.* (1996) have shown that under warm conditions (27.6°C), and when supplementary liquid milk was provided, the piglets consumed sufficient milk to attain a similar growth rate and weaning weight to the piglets weaned under cool conditions (20.7°C).

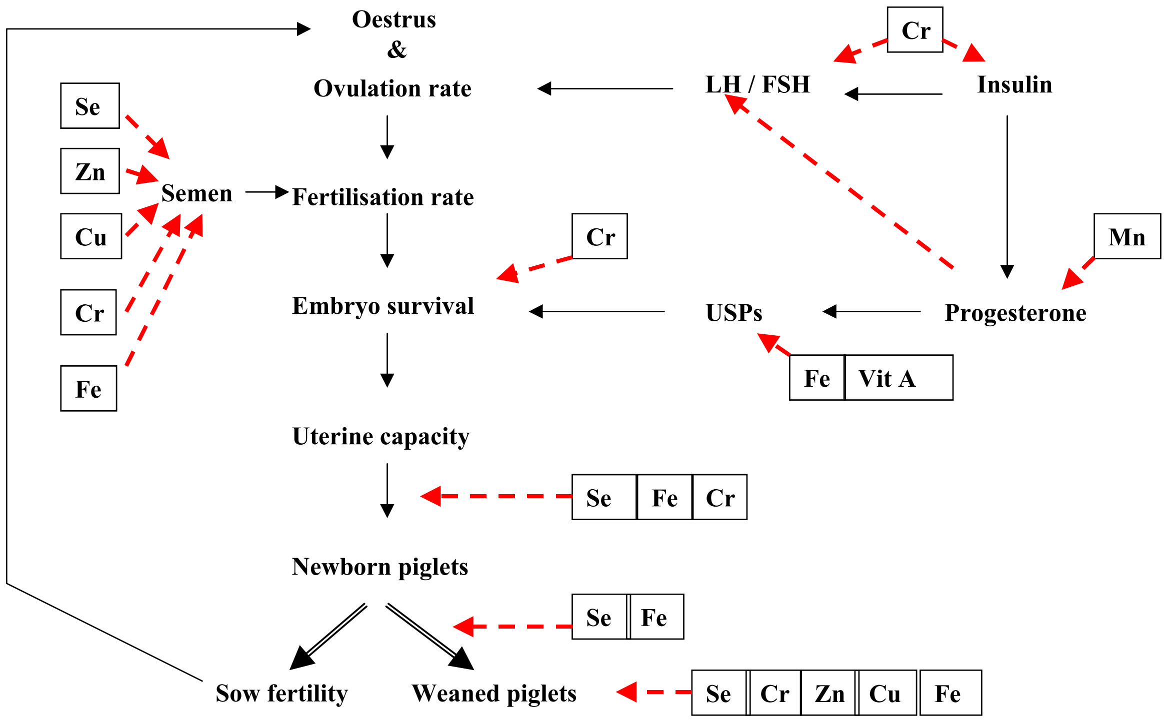
TRACE MINERALS AND REPRODUCTION

One of the possible reasons for the increased losses that occur in older sows may be associated with their reduced mineral status. Mahan and Newton (1995) have shown that the body mineral content of sows after the weaning of their third litter of pigs was significantly lower than that of unbred animals of similar age. In addition, the higher the level of productivity, that is the higher the body weight of the litter at weaning, the lower the maternal body mineral content. For some minerals, their content in the body was reduced by as much as 20%. This suggests that considerable de-mineralisation of the sow's skeletal structure occurred to meet the needs at the higher level of production.

These results raise questions about the actual mineral content in the diet, the availability of the minerals to the animal and the effect of the mineral status of the animal on overall productivity. This is especially pertinent to the sow, and Richards (1999) has shown that already in late gestation, the sow must rely on her liver iron reserves to meet foetal demands for the mineral. Perhaps this trend is halted when organic minerals are provided. The loss of minerals from the body is further exacerbated during lactation and this continuous drain on body reserves results in reduced mineral status as shown by Damgaard Poulsen (1993) and Mahan (2000). The lower mineral status of the sow is of course reflected in the mineral status of the piglet.

The question is: is it possible to protect the sow's mineral reserves from depletion while maintaining or increasing her reproductive performance? A closer look at the role of trace minerals in reproduction and how they are involved in the different components that determine litter size (Figure 5), may help us answer this question.

Figure 5. The potential role of trace elements in sow reproduction (Close, 1999b).



Several recent studies have been carried out to establish if high levels of dietary minerals could enhance sow productivity. For example, Cromwell *et al.* (1993) fed high levels of dietary copper to sows (250 ppm) over six parities and reported that their liver copper concentration increased by more than four-fold. There was no effect on reproductive performance, but birth weight and weaning weight of the piglets was increased. Fehse and Close (2000) fed highly productive sows a special package of organic minerals (iron, zinc, manganese, copper, chromium and selenium) additional to the normal level of inorganic minerals over a 2-year period. Over the peak parities (parities 3-6), 0.5 more piglets were weaned per litter (11.6 compared with 11.1) from those sows fed the additional organic minerals and pre-weaning mortality was also reduced. Interestingly, it was also observed that a greater proportion of the 'supplemented' sows remained in the trial for a longer period of time compared with the 'control' sows. These sows were better able to maintain good productivity and were retained in the herd throughout the most productive parities. Similar improvements in sow productivity have been reported in a trial including 26,000 sows (Smits and Henman, 2000).

It may well be that in the modern, hyper-prolific sow there is a gradual depletion of her mineral reserves and she is therefore unable to maintain long-term a high level of productivity. This may also affect her immune status. The provision of the additional organic minerals may stem the mineral loss from the body and better meet the needs of the animal, enhancing its metabolic, physiological and endocrine status and thus optimising sow productivity.

CONCLUSIONS

To achieve a high level of productivity in the modern sow, it is not sufficient to consider just the nutritional needs of the sow *per se* in terms of changes in body weight and body condition. It is equally crucial to apply nutritional and management strategies that reduce the loss of breeding potential, which is currently about 40% of the genetic potential of the modern hyper-prolific sow. Thus, it is important not only to supply sufficient energy and amino acids in the diet, but also minerals and vitamins in adequate quantities and in the most bio-available form. Similarly, good management practices must be applied to ensure the best health, welfare and well-being of the sow throughout its reproductive life.

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GROUP HOUSING OF SOWS – THE EUROPEAN EXPERIENCE

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ABSTRACT

Since January 1, 1999, it has been illegal to confine sows in stalls and tethers in the UK. The welfare lobby drove the requirement that producers group house sows. However, group-housing systems do not necessarily or inevitably improve welfare. Stereotypic behaviour, such as bar biting and sham chewing is not restricted to stall housed sows and is a reflection of inadequate nutrition rather than the sterile and unrewarding environment provided in sow stalls. Poorly designed and managed group housing systems can result in poor welfare. In particular, they can result in increased aggression and physical damage due to competition for food resources that do not result in satiety. Many of the problems created by group housing systems can be overcome by three factors. First, by increasing the fibre content of diets, feeding motivation can be reduced. This reduces competition for feed resources and increases the proportion of time sows spend resting. Secondly, the provision of bedding material that can be manipulated and eaten not only provides environmental enrichment, but also contributes to gut fill and satiety. Once again this reduces feeding motivation and improves the social environment. Thirdly, providing the sow with total protection whilst she is feeding ensures that she receives her complete ration and removes competition for feed, which is a major contributor to physical damage. Well designed and operated group housing systems using Electronic Sow Feeders (ESF's) provide the best environment for large groups of housed sows and can make a significant contribution both to improved sow welfare and sow feed management.

WELFARE LEGISLATION IN THE UK/EU

Consumer concern about the welfare of farm animals became an issue in the UK in the 1960's. This was largely a response to Ruth Harrison's book *Animal Machines* (Harrison 1964). Animal welfare organisations organised quickly, obtained extensive media coverage and became extremely effective lobbyists. In response, the UK government set up the Brambell Committee in 1964 with the remit:

'to examine the conditions in which livestock are kept under systems of intensive husbandry and to advise whether standards ought to be set in the interests of their welfare, and if so what they should be' (HMSO 1965).

An outcome of this committee was the establishment of the Farm Animal Welfare Committee, which was replaced in 1979 by the Farm Animal Welfare Council (FAWC). Using the principles implicit in the Brambell report, FAWC developed a basis for discussion and legislation on animal welfare that became know as the '*Five Freedoms'*. The Five Freedoms were later expanded with qualifying statements and these in turn formed the basis for the Code of Recommendations for the Welfare of Livestock: Pigs (Table 1).

Table 1. The Five Freedoms and their interpretation in the UK Pig Welfare Codes.

The Five Freedoms	Welfare Code provisions (1983)
1. FREEDOM FROM HUNGER AND THIRST - by ready access to fresh water and a diet to maintain full health and vigour. 2. FREEDOM FROM DISCOMFORT - by providing an appropriate environment including shelter and a comfortable resting area. 3. FREEDOM FROM PAIN, INJURY OR DISEASE - by prevention or rapid diagnosis and treatment. 4. FREEDOM TO EXPRESS NORMAL BEHAVIOUR - by providing sufficient space, proper facilities and company of the animal's own kind. 5. FREEDOM FROM FEAR AND DISTRESS - by ensuring conditions and treatment which avoid mental suffering.	• comfort and shelter; • readily accessible fresh water and a diet to maintain the animals in full health and vigour; • freedom of movement; • the company of other animals, particularly of like kind; • the opportunity to exercise most normal patterns of behaviour; • light during the hours of daylight, and lighting readily available to enable the animals to be inspected at any time; • flooring which neither harms the animals, nor causes undue strain; • the prevention, or rapid diagnosis and treatment, of vice, injury, parasitic infestation and disease; • the avoidance of unnecessary mutilation; and • emergency arrangements to cover outbreaks of fire, the breakdown of essential mechanical services and the disruption of supplies.

Despite this activity, Members of Parliament reported that they had more correspondence about animal welfare than any other issue. The construction of sow accommodation based on sow stalls and tethers was banned in October 1991, and the use of existing stall and tether systems was banned on 1 January 1999 (HMSO 1991). This unilateral decision of the British government was taken ahead of any planned EU legislation. This action was even more inexplicable given that at the time no more than 50% of UK sows were housed in stalls. The UK pig industry had never adopted stall housing to the same extent as other European countries or North America. The decision to ban stalls had far-reaching economic consequences for the British pig industry. Many producers lacked the confidence to reinvest in new housing, particularly as they were uncertain what other changes the welfare lobby (or the major food retailers) might demand. Many others simply lacked the resources to reinvest and left the industry. The remaining British pig producers are still feeling the repercussions of the stall ban, which has added significantly to their costs of production and has reduced their ability to compete with other European producers. Other EU producers will not face a complete ban on the stall housing sows until 2013, but still enjoy unrestricted access to the UK market.

It is an appropriate time to review the topic of group housing, as two new EU Directives (Directive 2001/88/EC & Directive 2001/93/EC) have just been enacted, which revise the European Welfare Regulations. In the UK, the provisions of these Directives have been enacted through an amendment to the Welfare of Farmed Animals Regulations (HMSO 2003) which came into force on 14 February 2003. The key paragraphs relating to the housing of non-lactating sows are summarized in Appendix 1. The complete document can be accessed on the Department of Environment, Food and Rural Affairs (DEFRA) website (DEFRA 2003).

In order to consolidate the provisions in this legislation DEFRA are also drafting a new Welfare Code for pigs, which can also be found on their website.

In addition to the legislative constraints, UK producers have also had to contend with the increasingly intrusive demands of the multiple retailers, who have added further constraints and restrictions through their Quality Assurance programmes. Although the retailers present the practices that they require as a reflection of the wishes of their consumers, there is little evidence that consumers have any understanding of many of the issues. Rather, the practices the retailers demand reflect the fierce competition in a retail sector dominated by 5 major retailers who between them account for more than 80% of meat sales. They promote specific values, such as a concern for animal welfare, as a part of their strategy of market differentiation and brand identification. In the UK, the retailer is the brand, not the product being sold. However, to the frustration of UK pig producers, the multiple retailers do not uniformly and consistently impose the same production standards on their overseas suppliers. Although market research surveys consistently indicate that consumers would be prepared to pay a premium for products derived from higher welfare systems of production the reality is that they have not been prepared to demand higher welfare, UK produced pig meat products. Price continues to be the most important factor affecting purchasing decisions.

GROUP HOUSING OF SOWS IN THE UK

The premature decision by the UK Government to ban sow stalls focussed the minds of British producers on the need to develop suitable systems for group housing the demanding, highly productive modern genotypes used on commercial units. In a survey, producers were asked what features they felt were important in group housing systems. Whilst most producers identified the capability to feed sows individually as being important (in order to prevent bullying and fighting), very few considered that having a system that permitted individual rationing of sows was important. The Pig Welfare Advisory Group (1993a; 1993b; 1993c; 1993d; 1993e; 1993f; 1993g; 1993h; 1993i) published a series of booklets outlining a range of options for the housing and management of group housed sows and included in their assessment the advantages and disadvantages of the different systems (N.B. these booklets can be accessed on the DEFRA website).

Of the various options that were available, the most widely adopted was outdoor sow housing. Given the mild climate in the UK, and on the right soil, some producers have been able to expand their herds rapidly and at a low capital cost by housing sows outdoors. In the early 1900's outdoor production was considered a low input, low output, system. Advances in husbandry have changed that view. The performance of modern outdoor units usually equals and can exceed that of indoor units (Table 2). For about 10 years, the multiple food retailers, who like their consumers perceived outdoor production as environmentally and welfare friendly, encouraged the move to outdoor production. For a time, circa 30% of UK sows were housed outside. However, lack of a market premium, and concern about disease transmission (particularly in the wake of foot and mouth disease) is resulting in outdoor units disbanding, or moving back indoors. Furthermore, it has been realised that outdoor sows can be extremely damaging to the structure of some soils and that the deposition of their excrement on defoliated land can pose a greater pollution threat than the controlled spreading of effluent from a confinement unit. There is no opportunity to individually feed sows on outdoor units. As a consequence, maintaining appropriate body condition can be problematic. Sows are almost invariably fed on the floor and a significant quantity of food can be wasted when weather conditions are unfavourable.

Table 2. Performance of indoor and outdoor sow herds (Meat and Livestock Commission 2001).

	Indoor herds	Outdoor herds
Average herd size	242	687
Annual replacement rate (%)	41.0	46.6
Litters per sow per year	2.26	2.25
Pigs born per litter	12.20	11.83
Litter reared per litter	9.76	9.84
Pigs reared per sow per year	22.10	22.20
Sow feed per year (tonne/sow)	1.23	1.41
Feed per pig reared (kg)	60	70
Feed cost per pig reared (£)	6.40	7.48

THE EFFECT OF HOUSING SYSTEM ON THE ABILITY TO RATION SOWS

This lack of recognition of the importance of individual rationing is a matter of serious concern to nutritionists. Modern sows start their breeding life with much lower body fat reserves than sows did twenty or even ten years ago, but at the same time they rear significantly more piglets. Moreover, the geneticists continue to increase both the lean content and the prolificacy of sows. If the sows we have today and the sows that we will have tomorrow are to stay productive, it is essential that we are capable of managing them in such a way that we can maintain their body fat reserves. This can only be achieved by treating them as individuals.

We can put this problem in perspective by looking at a couple of examples. The energy requirement of the pregnant sow increases from approximately 30 MJ DE/day at 120 kg live weight to approximately 40 MJ DE/day at 320 kg live weight. This represents a 33% increase in the feed requirement. If both sows were fed a 13.5 MJ/kg diet they would need respectively 2.2 and 2.9 kg feed per day. What appears to be a relatively small difference in daily intake amounts to over 80 kg feed during a 115-day pregnancy. Furthermore, the requirement of the sow increases by about 12% between mating and farrowing. Failure to satisfy the nutritional demands of the individual sow during pregnancy can result in excessive fat loss during lactation and this in turn leads to extended weaning to remating intervals and poorer litter performance. Depleted fat reserves also lead to breeding irregularities and to premature culling (Close and Cole 2000). Therefore, individual rationing is imperative if the productivity and the potential herd life of the sow is to be maintained.

Individual rationing is possible, but rarely practised, when sows are stall housed. It is equally possible in the rather old fashioned, but still very effective, yard and individual feeder systems (Pig Welfare Advisory Group 1993g). In Holland, a system that utilises voluntary stalls has also been developed. However, to provide effective rationing these systems require the daily identification of individual animals by the stockperson. This may be acceptable on the smaller, owner-operated unit where attention to detail has a high priority, but is not easily achieved on a large unit. A number of different housing and feeding systems have been adopted but there have been no systematic comparisons of the relative performance or operating costs of these different systems

Two systems that attracted some interest in the UK are Dump (or Spin) Feed (Pig Welfare Advisory Group 1993i) and Trickle Feed (also known as Biofix) systems (Pig Welfare Advisory Group 1993h). Dump feeders drop and Spin Feeders scatter the feed allowance for a group of sows into the straw-bedded lying area. One of the claims for this approach was that searching for food in the straw bedding would satisfy the behavioural need of the sows to forage. In reality, this is a poor attempt to justify a crude feeding system. At best, such an approach fails to provide any opportunity to control the intake of individual animals, at worst it causes considerable aggression and results in the entire bedded area being disrupted on a daily or twice-daily basis. There is no logic in providing a straw-bedded rest area and then making it the focus for intense feeding activity and aggression. As the sows still have to compete for feed the system cannot be regarded as ‘welfare friendly’. Many producers who have tried such systems have abandoned them very quickly.

In the case of Trickle Feed (Biofix) systems, each sow has a feeding space (usually a shoulder length stall). The feed is made available in that feeding space slowly (hence Trickle Feed) and this is supposed to ensure that all sows receive their allocation. Trickle Feeders reduce, but cannot totally eliminate competition for feed. In addition, they force the sows to adopt an abnormal feeding pattern. The feeding rate of all the sows in the group is adjusted to the eating speed of the slowest animal in the group. Questions remain to be answered about the degree of frustration that is caused by such a feeding regime and the impact that this has on sow welfare. In addition, such systems are not totally effective in reducing aggressive encounters, as the faster eating sows still leave their feeding spaces and try to displace and steal the food of other sows that are still feeding.

The welfare and behaviour of sows has recently been compared in small cubicle pens housing groups of four sows and a split-yard housing system (similar to that in Figure 1) housing a large dynamic group (Durrell *et al.* 2002). The latter system appeared to offer the sows a more stimulating social and physical environment, but also led to higher levels of aggression and skin damage.

ELECTRONIC SOW FEEDERS OVERCOME RATIONING PROBLEMS

The Electronic Sow Feeder (ESF) system was first developed back in the 1980's (Lambert *et al.* 1984; Smith *et al.* 1986). They enable sows to be individually fed, in a feeding station where they are protected from other sows. The daily ration for the individual sow can be determined and is delivered when the sow enters the feed station and is identified by the computer controlling the system. Sows are individually identified by means of a transponder. In early versions, this was carried on a collar, but most modern systems now use a transponder carried in an ear tag. Tags used a decade ago were quite large and obtrusive, and led to some problems of chewing and ear trauma (Sherwin 1990). The tags used today are little larger or heavier than a conventional identification tag. Experiments have been undertaken using implanted transponders. Unfortunately, implants have a tendency to move from the initial implantations site. This has two important consequences. First, they may not be recognised by the receiver in the feed station. Secondly, they may not be detected and removed at slaughter. Because of the adverse impact that this could have on consumers, this approach has not been adopted commercially.

If a sow loses her transponder she will not be identified by the feed computer and will receive no food. Therefore, it is an essential element of daily management that any sows recorded as not having fed are checked to see whether they still have an active transponder in place or not.

Electronic Sow Feeders overcome the majority of problems intrinsic in other group housing systems and have some additional advantages, namely:

- They allow sows to be housed as a group but fed as individuals.
- They provide opportunities for the stockperson to exercise a very high degree of feed management (i.e. programming rations to meet the specific and changing requirements of individual sows).
- They allow sows to adopt an individual and flexible feeding pattern (within the constraints imposed by feeder use by the other sows in the group).
- They minimise aggressive encounters associated with feeding by removing competition for food.
- They allow sows living in a group to exercise a high degree of control over their thermal environment.
- They enable sows to enjoy a very rich and varied repertoire of behaviour, particularly if provided with bedding material.

Unfortunately, ESF systems got off to a bad start in Europe. Any researcher reviewing the literature up until 1995-6 could be forgiven for concluding that these systems presented more problems than solutions (Broom *et al.* 1995; Jensen *et al.* 1995; Kroneman *et al.* 1993; Olsson *et al.* 1992; Simmins 1993; Stamer *et al.* 1992; Taureg *et al.* 1991a; Taureg *et al.* 1991b). However, most of these reports in the literature are of little or no value today. The equipment used in the early studies had intrinsic design faults that only became apparent with the commercial adoption of the systems. In addition, many of the published studies involved housing designs and sow group sizes that have no relation, or relevance, to the systems that are now used on commercial units. Many of the initial ESF systems were sold onto farms before adequate research and development had taken place. As a result many of the 'early adopters' had to overcome teething problems with their systems. A lot of good, but less determined producers gave up. The remainder persevered with their ESF systems, often making numerous changes to the feeders and to building design until, by trial and error, they learnt how to construct and operate an effective system. It is a tribute to their efforts that there are now a number of variants that will produce excellent results. There are now producers in Europe, North America and Australia, who are convinced not only that ESF systems work but also that group housing using ESF is the only way of keeping sows.

It is always difficult to make comparisons of 'systems' as so many management variables can affect performance and bias results. However, as long ago as 1994 data generated from the Feed Recording Scheme run by the Meat and Livestock Commission in the UK demonstrated that systems based on ESF's could produce as good biological outputs as any other system (Tables 3 & 4).

Table 3. Performance of herds using Electronic Sow Feeders (ESF) compared with the average of all other forms of housing (Meat and Livestock Commission 1994).

	ESF herds	All herds average
Number of herds	23	305
Litters per sow per year	2.31	2.24
Non-productive days per year	30	38
Pigs reared per sow per year	21.7	21.4
Average number of pigs born	10.7	10.81
Average number reared per litter	9.41	9.54
Feed per sow per year (tonne)	1.21	1.31

Table 4. Comparison of performance of sows in herds using Electronic Sow Feeders, conventional yards and feeders or stalls and tethers (Meat and Livestock Commission 1994).

	ESF	Yards	Stall/Tether
Average number of pigs born	11.62	11.76	11.64
Average number reared per litter	9.41	9.51	9.51
Mortality of pigs born live	12.0	12.6	11.3
Pigs reared per sow per year	21.7	21.0	21.7

The University of Plymouth was an early adopter of the ESF system and the research team there spent several years remodelling and re-engineering both feeders and buildings before learning how to make a system that would work effectively. An analysis of the data from the system operated at the University of Plymouth for seven years between 1990 and 1997 (Table 5) indicated that performance was equal to, or exceeded that of the top third of producers recording with the MLC scheme during that period.

Table 5. Comparison of performance of the Seale-Hayne herd (using ESF) with average and top third herds recording with the Meat and Livestock Commission (1990-1997) (Hodgkiss 1998).

	Seale-Hayne	MLC average	MLC top third
Services: farrowings (%)	87.93	86.60	87.74
Pigs born live per litter	11.41	10.85	11.23
Pigs born dead per litter	1.25	0.80	0.82
Total pigs born per litter	12.94	11.76	12.17
Sow cullings and deaths (% per year)	36.71	41.11	41.06

A recent publication (Bates *et al.* 2003) confirms that sow perform as well in an ESF system as they do in stalls (Table 6).

Table 6. Performance of sows housed in stalls or in a group fed using ESF (Bates et al. 2003).

	ESF	Stalls
Farrowing rate (%)	94.3	89.4
Litter birth weight (kg)	17.7	16.7
Litter weaning weight (kg)	57.1	56.2

However, the design of the installation has a major effect on its operation. When ESF's were first introduced producers were led to believe that they could be installed in virtually any building design and they would work. This proved incorrect. The design of the equipment and the layout of the building are extremely important. ESF systems are normally operated with a large numbers of animals living together in a dynamic group (that is a group where some sows are relocated to the farrowing house each week and other sows rejoining the group following weaning or service). Because of this, the behaviour of the sows is of paramount importance. Some important lessons have been learned from early mistakes. Among these, the most important lesson is that relatively small differences in the feeding equipment and the layout of the building can have profound effects on the behaviour of individuals and the group. As a result of some of the lessons that have been learned, certain recommendations can be made for those planning new installations.

IMPORTANT DESIGN FEATURES FOR ESF INSTALLATIONS

Avoiding Damage To The Sow

Initial ESF designs failed to give the sow sufficient protection while eating. This had two main effects. First, some sows were reluctant to use the feed station, as they felt vulnerable to attack. Timid sows would also vacate the feeder, leaving feed behind and thereby not getting their complete ration. Secondly, some herds experienced significant problems with vulva biting (Gjein *et al.* 1995; Lembeck *et al.* 1995; Maton *et al.* 1990; Rizvi *et al.* 1998; Svendsen *et al.* 1992b). Some early designs required that the sow back out from the ESF, and sows waiting to enter frequently attacked sows exiting the feeder. Keeping a boar in with the group of sows was also implicated in vulva biting, particularly if he was fed in the ESF.

The following recommendations can be made.

1. Feeding stations must be 'walk through'. Rear exit systems lead to aggressive encounters and physical damage (fighting and vulva biting).
2. Feeding stations must operate in a way that ensures the total security of the sow while feeding and gives her some warning that the rear gate is going to be unlocked, thereby giving her an opportunity to vacate the feed station before another sow attempts to enter.
3. Boars should not be fed in the ESF. They are extremely competitive and contribute to damage. A boar fed outside the ESF will not allow his food to be stolen!

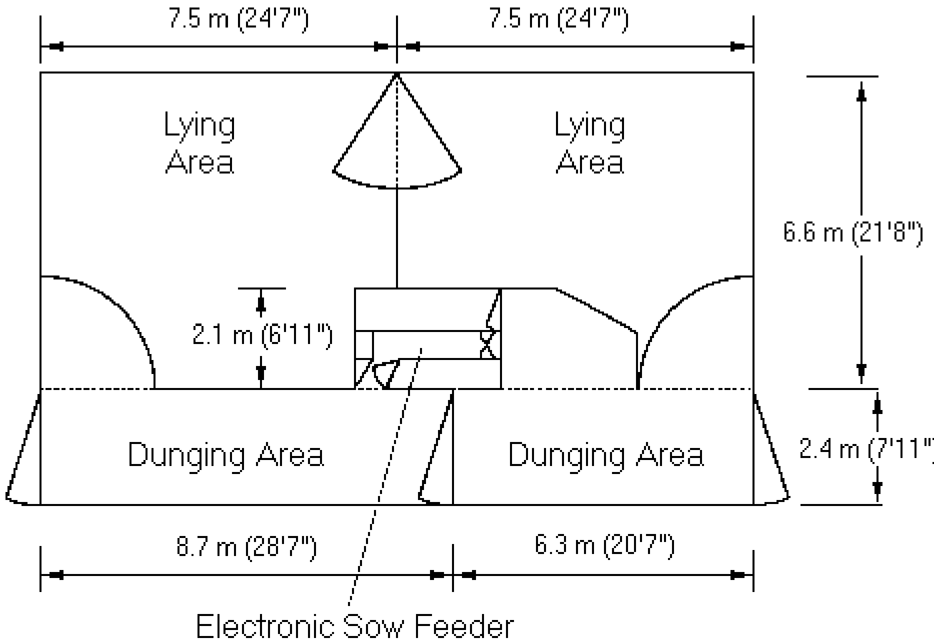
Reducing Non-Feeding Visits

Feed troughs should not be available to sows that have consumed their daily allowance. The better designs either swing the trough to one side or lower a shutter to make it unavailable.

Although this may appear to result in more complicated engineering, it is a great benefit as it reduces the number of non-feeding visits and allows more sows to be fed through one feeding station. In addition, it increases the life of the system. Designs in which feed left in a trough is available to a sow who has no feed balance remaining, or where by repeatedly banging the feeder the sow may dislodge feed from the delivery auger into the trough, encourage sows to make repeated returns to the feeder to try and gain additional feed. If they get any feed (reward) this behaviour is encouraged and consequently repeated time and again, with detrimental effects on the equipment. This can also lead to a herd being overactive and disturbed all the time. Systems in which the sows cannot get any feed reward for what should be non-feeding visits are notable for their peaceful atmosphere.

Some producers have attempted to solve this problem by designing units in which the sows are penned on one side of the feeder and enter a second pen having fed (Figure 1). The aim of this approach is that sows wishing to feed will not have to compete for access with sows making non-feeding visits. At the end of the feeding period it will be immediately obvious to the stockperson which sows have and have not fed. However, this design does impose on the sow the necessity to take all her feed at a single visit (unless the process is repeated more than once in each day).

Figure 1. 'Walk-through' layout. Sows pass from one lying area to the other via the Electronic Sow Feeder and are then returned as a group when all have fed.



Sows should be permitted to take their entire daily ration at a single feed if they wish, but they should not be forced to take all their daily allowance at one feed. Studies undertaken at the University of Plymouth have shown that there is great variation between sows in the number of meals that they wish to take in a day (Eddison *et al.* 1995; Hodgkiss 1998). The number of meals taken each day and the feeding sequence of the group is not a constant and this must be accommodated by the equipment (Bressers *et al.* 1993; Lembeck *et al.* 1995).

It is better not to provide water in the feeding station. Sows will not remain in the station after feeding if there is no water. They will go out to drink. Some of the newer feed stations use liquid feed delivery, which can increase throughput and also has the advantage that a much wider range of feed materials can be utilised.

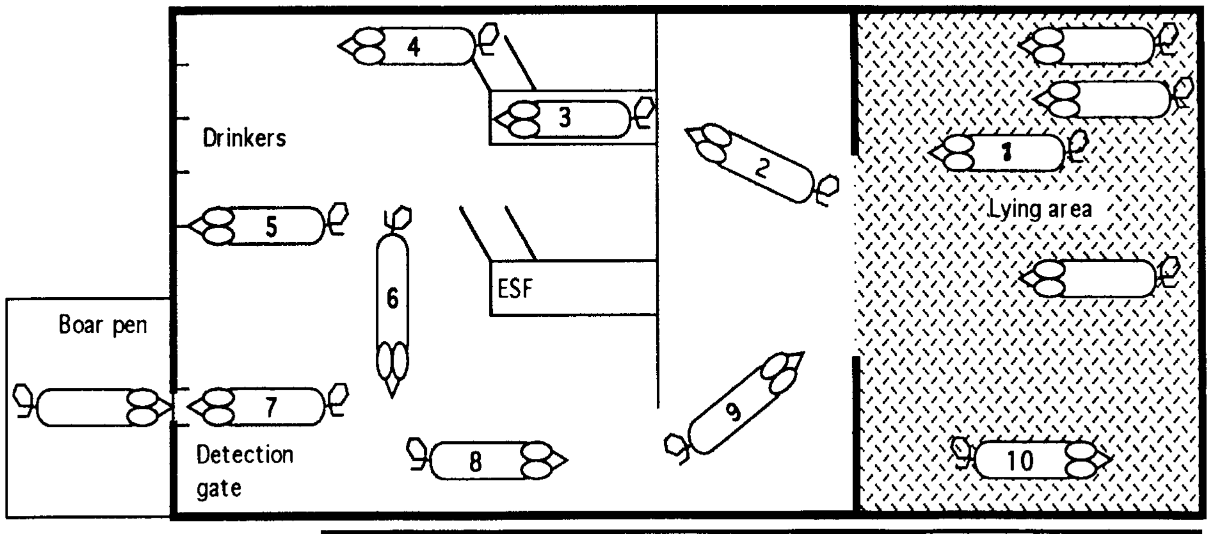
Where dry feed is used, pelleted feed is preferable to meal as it helps to avoid bridging in bins and feeders. If bridging occurs this can cause problems as the computer registers that the sow has eaten when she has not.

The bulk density of the feed must be checked regularly. Most systems deliver feed on a volumetric basis. As a consequence a failure to check and adjust for differences in bulk density of the diet being fed can result in a significant loss of accuracy in rationing sows.

The Building Layout

The layout should attempt to anticipate the natural sequence of sow activities and create a circuit that the sow will follow. This is shown schematically in Figure 2. Creating a natural circuit reduces confrontations and competition for resources. This can be achieved without the need for extended exit races.

Figure 2. Schematic indicating a layout that allows sows to perform behaviours in an appropriate order.



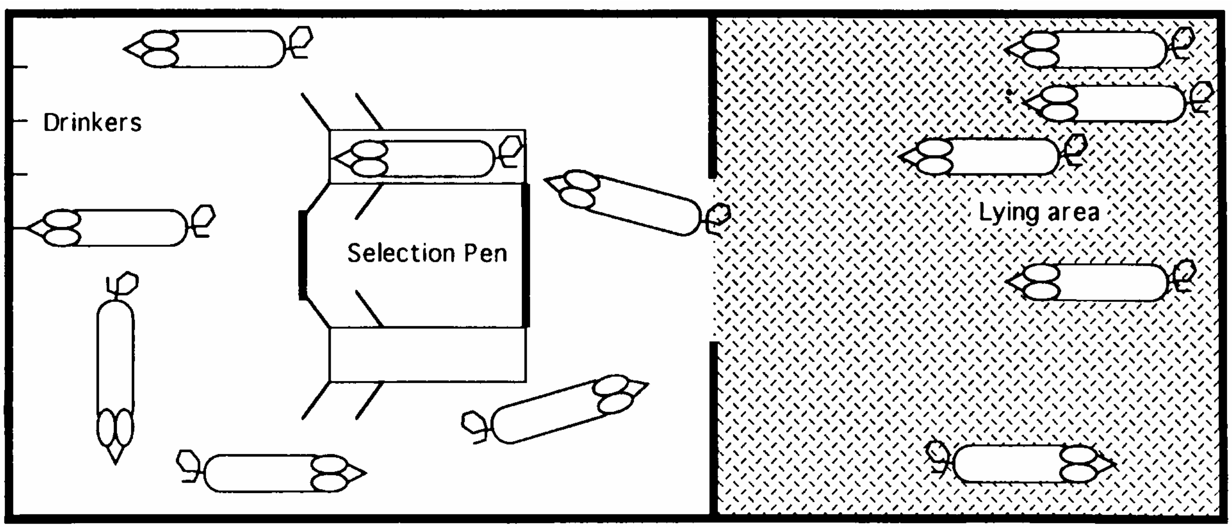
Explanation

1. Sows resting in lying area. Ideally they should have line of sight to the feeder. The next sow in the feeding queue may not be the one nearest to it!
2. Sows waiting to enter the feeder should neither obstruct nor be obstructed by sows returning from the dunging area. This minimises agonistic encounters.
3. Sow must be completely protected while feeding.
4. Sows must be able to exit the feeder with out fear of being attacked by other sows. Therefore, the exit gate must not allow any sow to enter the feeder from the wrong side.
5. Drinkers should be positioned away from the feeders in the dunging area so that sows are drawn away from the feeders once they have exited. In hot climates nose operated sprays can also be positioned in this area so that sows can cool themselves.
6. Sows will dung and urinate after eating/drinking.
7. If an oestrus detection gate is to be included in the design this should be positioned so that it draws sows away from the main thoroughfare. This will minimise agonistic encounters
8. Return route to the lying area should direct the sow away from the feed queue.
9. Returning sow should have a good view of the lying area and the access to it should be wide enough so that agonistic encounters are reduced.
10. Returning sow locates an appropriate resting place.

The use of a two-station module represents good risk management. If a mechanical breakdown occurs in a two-station pen the remaining station will cope, in the short term, until the second feeder can be repaired. If only one station is provided in a pen a mechanical breakdown can prove extremely difficult to manage. Sows that are not used to competing for food should never be floor fed. If the system has straw bedding, copious new bedding should be provided until the system can be repaired.

Most companies selling ESF's offer the option of a shedding gate that will allow sows to be diverted into a selection pen (Figure 3). This would appear to be a valuable management aid. However, experience on commercial units has shown this not to be the case. As any selected sow may be in this pen for quite long periods (e.g. overnight), the selection pen must provide a warm and comfortable environment and must be provided with its own water supply. This is an additional constraint on the design that is not always easy to provide. A more important factor is that sows will often resist exiting through an unfamiliar gate. This can result in sows attempting to back out of the unit and being damaged by other sows in the process. The preferred approach is to fit the feed station with one or more computer-operated spray markers that can mark selected sows as they go through the system. This prevents the normal routine of the sows being disrupted. In a well-managed unit the sows become very docile and finding and removing a marked sow from the group is extremely easy. Very large group sizes should be avoided, not because they don't work but because the observation, identification and removal of individuals becomes very time consuming. Multiples of 80-100 sows, on 2 stations or 120-150 sows, on 3 stations seem to work very well.

Figure 3. Two-feeder layout incorporating a selection pen.



A Training Pen For New Entrants Is Essential

The gilt / sow must be well trained before joining the main herd. It is beneficial to arrange the training pen so that the incoming animals can see, smell and touch the sows already in the main group before they join it. Ideally, they should be able to see experienced animals using the feed station. This enables them to become familiar with the system before they have to operate it and ensures that they have no fear of the feeder when they are first introduced to it.

When they are introduced to the system they should be allowed plenty of time to explore the feed station and should be encouraged to enter by scattering some food on the floor. They should never be pushed or forced into the pen. A good stockperson should have no problem training gilts to use the system. Never the less a very small number of animals may prove to be untrainable and have to be removed from the system. On large units, it is important that all the pens have a similar layout or that sows always return to the same pen. Failure to do this can increase the amount of retraining required.

Entries to and exits from the feeders should not involve the sows going up and down steps or steep slopes. Both tend to impede the flow of animals and also lead to a higher incidence of foot and leg damage. The areas immediately around feeder entries and exits should be as free of impediments as possible and barriers and corners which could leave a sow feeling trapped must be avoided.

Feed stations should not be placed directly against walls and the exit from feeding stations should be well away from the entrance to another in order to improve the flow of sows. (Figure 4 & 5). Such an arrangement gives only a 90° approach angle and tends to deter timid sows from approaching the feeder. Feeders should be placed in such a way that they provide a 180° approach angle to the feeder (as in Figure 2). In some installations, the feeders have been placed so that the sows can circulate all around them. Allowing access all around the feeder can be beneficial in small units as it allows sows to avoid confrontations where space is restricted around the feed stations.

Figure 4. Avoid positioning feeders such that the approach angle is reduced or the exit impeded by other sows.

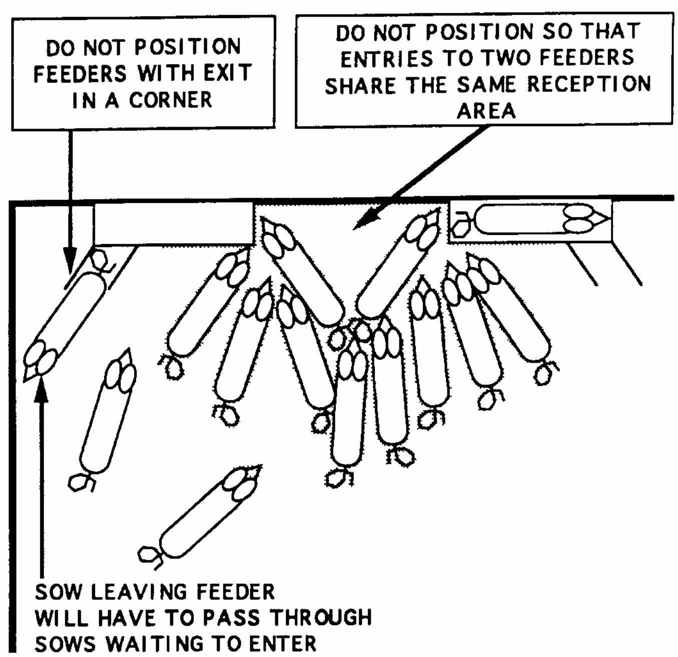
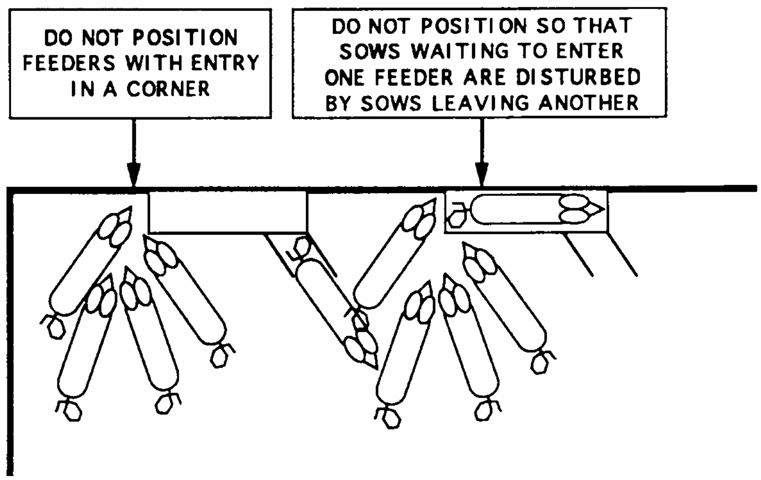
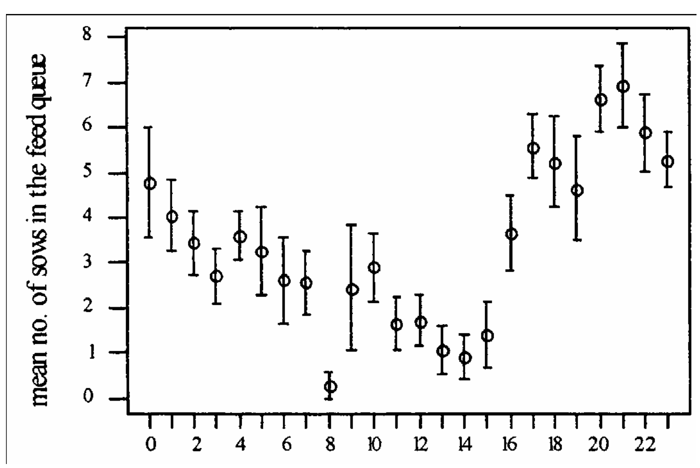


Figure 5. Avoid positioning feeders such that sows exiting from one feeder impede sows entering another.



Ideally, the building should be designed so that the feed stations can be seen from the lying area. This allows sows to keep an eye on the feed station while continuing to rest in the lying areas. Our observations suggest that sows are very like humans! Most of them do not like hanging about in queues. Consequently, they will stay in the lying area and only get up to feed when they judge the feeding queue to be short enough. If they can see easily who is waiting to feed, timid sows will avoid going up to feed when more dominant sows are waiting in the vicinity of the feed station. This allows the sows to avoid aggressive encounters and contributes to the peaceful atmosphere that characterizes successful installations. If the unit is laid out in the way suggested above there are rarely more than four or five sows in the area of each feeder even at busy times (Hodgkiss, 1998) (Figure 6). Finally, it is worth noting that the more dominant sows are not necessarily the first to eat in the daily feeding cycle. A dominant sow will demand access to the feeder when she wants to eat and this can be at any time in the twenty-four hours.

Figure 6. Number of sows in the feeding queue at different times of the day. (Two feed stations; 55-70 sows in the group; feed cycle starting at 1600h).



Opinions differ about the ideal time to start the feed cycle. A recent Dutch study found that changing the start of the feed cycle to late in the day reduced feeder occupation in the period following the start of the feeding cycle (Jensen *et al.,* 2000). The pig is by nature a twilight feeder, so starting the cycle late in the day would seem to fit in well with the natural instincts of the pig. A late afternoon start has a number of practical advantages namely:

- The busiest time at the feeders is at a time of day when the stock person has no need to be in the unit performing any tasks such as moving sows.
- The vast majority of sows will have fed by the time the stockperson starts work the following morning. This enables the stockperson to check the action list and identify any sow that has not fed.
- Sows being returned to the unit will be introduced when activity levels are lower thereby reducing aggression (N.B. sows should have been fed before being returned to the unit so that they are not motivated to use the feeders immediately on their return).
- The stockperson quickly gets to know sows that always chose to eat late in the feeding cycle and also to spot sows that they would have expected to have eaten by the time that they start work.
- Non-feeding sows can be checked for lost transponders, or ill health during the normal working day. In either case, they will need attention. However, feeding order is too unpredictable to be used to create action lists for attention (Bressers *et al.* 1993).

The Individuality Of The Sow

There is great variability in the way in which individual sows use the system. At Plymouth we found that the ESF system worked well with a dynamic group of sows; that is a group in which sows are continually removed to farrow and reintroduced following service. We monitored 65,000 feeder visits over an 18-month period (Eddison *et al.* 1995). This study has produced some interesting information, namely:

- That the number of visits made to the feeder in a day varied greatly from sow to sow (from 1-35).
- That sows vary in the amount of feed that they take in a single visit. Some sows always take all their allowance in a single feed. Others made several visits taking only small quantities of feed at each visit (range 1-14 visits per day).
- The visit duration and rate of eating varied considerably between sows. Some non-feeding visits last only seconds whilst one sow liked the feed station so much she went to sleep in it for 6 hours! Sows are not protected within the feeder for more than a couple of minutes after the last of their ration has been delivered, so had another sow wished to use the feeder she could have pushed out her sleeping pen mate.

In her detailed study of behaviour and welfare of sows in the Plymouth ESF unit, Nikki Hodgkiss made some other interesting findings (Hodgkiss 1998; Hodgkiss *et al.* 1998). Sows are very social animals and form relationships that can last for years even if they are separated for periods of time by lactation. Sows spent circa 25% of their time resting in association with other specific females either from the same service group or from the same gilt group (Table 7).

Table 7. The proportion of occasions on which sows were found resting in association with specific individuals (Hodgkiss 1998).

	Sow from the same service group	Sow from the same gilt group	Most frequent companion
Mean	0.26	0.27	0.22
SE mean	0.03	0.05	0.03

Feed Intake And Feeding Motivation

One of the Five Freedoms states that animals should have *'freedom from hunger and thirst - by ready access to fresh water and a diet to maintain full health and vigour'*. In the case of pregnant sow this is a contentious issue. A vast amount of research has been undertaken to determine the nutrient requirement of the sow and this has been used in the derivation of feeding recommendations (Close *et al.* 2000; National Research Council 1998). However, when sows are group housed not only their nutrient requirements but also their feeding motivation needs to be considered. A detailed discussion of feeding motivation in sows is beyond the scope of this paper but a few relevant points are worth reiterating.

We have been aware for many years that diets that meet the nutrient requirement of the sow do not satisfy her feeding motivation (i.e. the sow remained hungry and motivated to seek food). Workers in Edinburgh demonstrated that stereotypic behaviour in stall-housed sows resulted from hunger rather than boredom. In tethered gilts, stereotypic behaviour was almost totally eliminated when feed intake was increased from 1.25 to 4 kg per day (Appleby *et al.* 1987). Pigs fed 1.3 times maintenance were still unsatisfied in terms of their feeding motivation (Lawrence *et al.* 1989a; Lawrence *et al.* 1988; Lawrence *et al.* 1993). They also found that recommended feed intakes represented only 60% of the amount of feed that pigs would choose to eat if offered feed *ad lib.* As a consequence animals were motivated to feed for 19 hours of the day (Lawrence *et al.* 1989b). The feeding motivation is so strong that sows will work for feed to the extent that they sustain an energy deficit in order to gain more food (Hutson 1991). More recently, Hodgkiss (1998) investigated the feeding motivation of sows. She fed pregnant sows for 12 days either a conventional diet *ad libitum*, or 2.5 kg per day of a conventional diet (adequate to meet their nutrient requirements) followed by *ad libitum* access to soaked, unmolassed, sugar beet pulp (Figure 7).

Over the twelve-day period sows fed the conventional diet consumed 7.8±0.14 kg food per day. The sows offered a high fibre diet consumed 11.9±0.14 kg per day. Despite this they still had an energy intake around 50% of the sows on the conventional diet and well in excess of the supposed nutritional requirement.

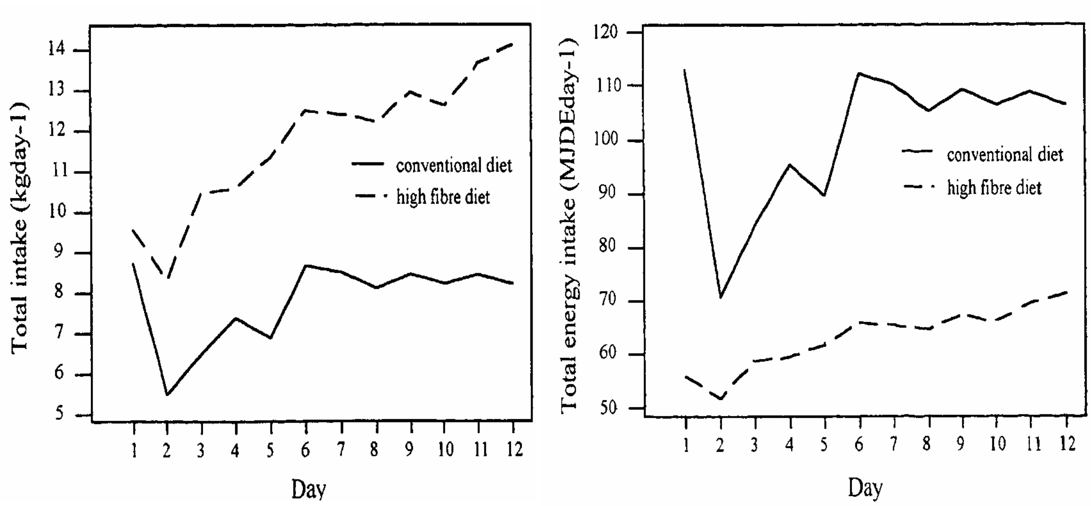
A number of studies have examined the effect of feeding lower density diets. These have recently been reviewed by Meunier-Salaun *et al.* (2001). They concluded that incorporation of fibre in diets to increase bulk, without changing the daily dietary energy supply, resulted in:

- At least a doubling of eating time,
- A 20% reduction in feeding rate,

- A 30% reduction in operant response in feed motivation tests,
- A reduction of 7-50% in stereotypic behaviour,
- A decrease in general restlessness and aggression.

Many fibre sources cannot be used effectively as they are either too bulky to handle or make the diet too expensive. However, where if it is available at an acceptable cost, the incorporation of unmolassed sugar beet pulp into diets appears to be beneficial (Hoy *et al.* 2001; Meyer *et al.* 2001; Tabeling *et al.* 2002; Whittaker *et al.* 2000; Whittaker *et al.* 1999; Whittaker *et al.* 1998). Commercial producers in the UK have used sugar beet pulp very effectively to reduce excessive non-feeding visits and to reduce activity levels in their units.

Figure 7. Feed and energy intake of pregnant sows fed a conventional diet ad lib. or 2.5 kg of a conventional diet plus ad lib. soaked, unmolassed, sugar beet pulp (Hodgkiss 1998).



STRAW BEDDING PREFERRED

There is no doubt that ESF systems work best in conjunction with bedded lying areas. Given ample bedding the sows are able to adjust their thermal environment. In some Northern European countries sows are housed in relatively low cost buildings with little environmental control (Svendsen *et al.* 1992a). In such circumstances straw bedding is essential in order to maintain an acceptable environment. The provision of straw bedding may also reduce the nutritional requirement of the sow (Simmins *et al.* 1994). This is less likely to be through a contribution to energy supply but through a reduction in energy loss. Ideally, the housing system should provide a variety of opportunities for the sow to modify her thermal environment. Straw bedding is of great benefit in this respect. Operators with straw bedded systems will point out that the size of the area that the sows designate for sleeping varies greatly with the time of the year and the thermal environment. In cold weather a relatively small surface area is utilised and the sows huddle together for warmth. A good depth of straw is advisable under such conditions so that the sows can bury themselves in it when very cold or form it into nests. This reduces ground level air movement and dramatically reduces the heat loss of the sow. In hot conditions the sows only need sufficient straw to make the floor surface comfortable. Sows in such straw bedded systems are very much less prone to developing the pressure sores, which are found on sows which are permanently housed on bare concrete.

However, this does not mean that the sows need to be maintained in an area, which is completely covered with straw. On the contrary, this actually reduces the sow's capability to control her temperature. In our system, we have observed that sows will often chose to lie on bare concrete when the ambient temperature is high in order to increase body heat loss. To deny them this opportunity would reduce their freedom to choose an appropriate temperature. In our system, the sows also have the use of a small paddock when the weather is good. Naturally, like sows kept outdoors all the year round such sows can suffer from sunburn if not provided with a wallow. The wallow not only affords them some protection from sunburn but also it provides the sows with another opportunity to adjust their body temperature. Sows that are not allowed to go out and wallow could become overheated in hot weather. Behaviourally, they attempt to overcome this problem by wallowing in the dunging area. This is not desirable from a health point of view. This problem can be overcome by incorporating a sow-operated shower into the design of an ESF system to provide a clean cooling system for the sows, which doesn't adversely affect the rest of the environment.

Activities related to the straw enrich the environment of the sow and provide them with the opportunity to perform a wide range of behavioural activities. The new EU welfare regulation has accepted that pigs are intelligent and investigative animals and that their housing frequently provides no outlet for these behavioural needs. Consequently, they have included in the regulations a requirement that:

> *To enable proper investigation and manipulation activities, all pigs must have permanent access to a sufficient quantity of material such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such which does not adversely affect the health of the animals.*

The 2003, UK, Pig Welfare Code adds that:

> *Environmental enrichment provides pigs with the opportunity to root, investigate, chew and play. Straw is an excellent material for environmental enrichment as it can satisfy many of the pigs' behavioural and physical needs. It provides a fibrous material which the pig can eat; the pig is able to root in and play with long straw; and, when used as bedding, straw can provide the pig with physical and thermal comfort.*
>
> *Objects such as footballs and chains can satisfy some of the pigs' behavioural needs, but can quickly lose their novelty factor. The long-term use of such items is not, therefore, recommended unless they are used in conjunction with materials such as those listed above, or are changed on a weekly basis.*

SYSTEMS WITHOUT STRAW

There is no doubt that ESF systems work best when combined with straw bedding. However, will they work without straw? In the author's view they can, but they do not work as well and can severely compromise the sow's welfare. Commercial systems that operate well without straw all have one common feature, namely, the sows have access to some bulk material, or feed, on a regular basis. Providing straw for consumption and / or entertainment from a hayrack, rather than bedding the sows on it, seems to be quite effective. On other units sows have been given grass or maize silage in addition to their compound diet. As indicated above, operating a group housing system with conventional diets, in a barren environment will not satisfy either the feeding or investigative behaviour of the sow.

CONCLUSIONS

Changing sows from confinement to group housing of sows poses many problems for the producer. Containment in stalls has allowed us to impose unacceptable constraints on the sow's activity and behaviour and to ignore the fact that we are denying her a number of the Five Freedoms. Group housing does not in itself solve all the problems of animal welfare. Indeed, if the housing and feed management of the sow is inadequate, welfare may be compromised every bit as much in a group housing system. However, this should not be used as an excuse for retaining stall housing. Group housing can work extremely effectively.

The greatest challenge for the industry is to identify, train and retain stockpersons who can operate and manage loose housing systems effectively. Those working with group-housed sows need a detailed understanding of animal behaviour, highly developed perceptual skills, initiative and an empathy with their animals. The industry needs a new generation of stockpersons who are proud to be practitioners of good 'husbandry', although they may now see themselves as practitioners of 'applied animal ethology'!

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APPENDIX 1

Council Directive 2001/88/EC and Commission Directive 2001/93/EC, which were adopted in October 2001 amend Directive 91/630/EC, which lays down minimum standards for the welfare of pigs. The Directives came into effect in all Member States on 1 January 2003. They have been implemented in England through the Welfare of Farmed Animals (England) (Amendment) Regulations 2003 (S.I. 2003 No. 299) which came into force on 14 February 2003.

Relevant Sections Of The Welfare Of Farmed Animals (England) (Amendment) Regulations 2003

Tethering

4. No person shall tether or cause to be tethered any pig except while it is undergoing any examination, test, treatment or operation carried out for any veterinary purpose.

Accommodation

6(1) A pig shall be free to turn round without difficulty at all times.

6(2) The accommodation used for pigs shall be constructed in such a way as to allow each pig to -
- (a) stand up, lie down and rest without difficulty;
- (b) have a clean, comfortable and adequately drained place in which it can rest;
- (c) see other pigs, unless the pig is isolated for veterinary reasons;
- (d) maintain a comfortable temperature; and
- (e) have enough space to allow all the animals to lie down at the same time.

7(1) The dimension of any stall or pen used for holding individual pigs in accordance with these regulations shall be such that the internal area is not less than the square of the length of the pig, and no internal side is less than 75% of the length of the pig, the length of the pig in each case being measured from the tip of its snout to the base of its tail while it is standing with its back straight.

7(2) Paragraph 7(1) shall not apply to a female pig for the period between seven days before the predicted day of her farrowing and the day on which the weaning of her piglets (including any piglets fostered by her) is complete.

Artificially lit buildings

8. Where pigs are kept in an artificially lit building then lighting with an intensity of at least 40 lux shall be provided for a minimum period of 8 hours per day subject to paragraph 16 of Schedule 1 to these Regulations.

Bedding

11. Where bedding is provided, this must be clean, dry and not harmful to the pigs.

Floors

12. Where pigs are kept in a building, floors shall -
- (a) be smooth but not slippery so as to prevent injury to the pigs;
- (b) be so designed, constructed and maintained as not to cause injury or suffering to pigs standing or lying on them;

(c) be suitable for the size and weight of the pigs; and
(d) where no litter is provided, form a rigid, even and stable surface.

13. When concrete slatted floors are used for pigs kept in groups the maximum width of the openings must be….
(d) 20 mm for gilts after service and sows.

Feeding

14. (1) All pigs must be fed at least once a day.
(2) Where pigs are housed in a group and do not have continuous access to feed, or are not fed by an automatic feeding system feeding the animals individually, each pig must have access to the food at the same time as the others in the feeding group.

Drinking water

15. All pigs over two weeks of age must have permanent access to a sufficient quantity of fresh drinking water.

Environmental enrichment

16. To enable proper investigation and manipulation activities, all pigs must have permanent access to a sufficient quantity of material such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such which does not adversely affect the health of the animals.

Noise levels

18. Pigs shall not be exposed to constant or sudden noise. Noise levels above 85 dBA shall be avoided in that part of any building where pigs are kept.

Group housing

36. Sows and gilts shall be kept in groups except during the period between seven days before the predicted day of farrowing and the day on which the weaning of piglets (including any piglets fostered) is complete.
37. The pen where the group is kept must have sides greater than 2.8 m in length, except when there are less than 6 individuals in the group, when the sides of the pen must be no less than 2.4 m in length.
38. The total unobstructed floor area available to each gilt after service and to each sow when gilts and/or sows are kept in groups must be at least 1.64 m^2 and 2.25 m^2 respectively. When these animals are kept in groups of less than 6 individuals the unobstructed floor area must be increased by 10%. When these animals are kept in groups of 40 or more individuals the unobstructed floor area may be decreased by 10%.
39. For gilts after service and pregnant sows a part of the area required in paragraph 38 equal to at least 0.95 m^2 per gilt and at least 1.3 m^2 per sow must be of continuous solid floor of which a maximum of 15% is reserved for drainage openings.
40. Sows and gilts kept on holdings of fewer than 10 sows may be kept individually provided that their accommodation complies with the requirements of paragraphs 6 & 7.
41. In addition to the requirements of paragraph 14, sows and gilts must be fed using a system which ensures that each individual can obtain sufficient food even when competitors for the food are present.
42. All dry pregnant sows and gilts must be given a sufficient quantity of bulky or high fibre food as well as high energy food to satisfy their hunger and need to chew.

TECHNIQUES TO FINE-TUNE REPRODUCTION

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ABSTRACT

When an analysis of herd records indicates relatively good fertility, there may still be room for further improvements. Herd output can be measured as weaned pig production. However, while the average number of pigs weaned per week may be good, weekly production may not be consistent (e.g. +/- 10%). Fine-tuning reproduction may allow increases in pig production, or just improve consistency of production. This may be achieved by consistently meeting breeding targets, or by improvements in farrowing rate or litter size. This paper will examine the potential to fine-tune the control of estrus and breeding management to aid the achievement of maximum reproductive output.

INTRODUCTION

Techniques to fine-tune the reproductive performance of the sow-herd may be farm-specific, i.e. may work on one farm but not another. To make a decision concerning the use of a particular technique, and to determine why the technique may or may not work, an understanding of the biology of reproduction is necessary.

Before considering the implementation of any technique to improve herd fertility, knowledge of the sow herd's current performance is needed. This requires detailed records since if you cannot measure it, you cannot manage it. With knowledge of current performance, you can decide where improvements may be made. To this end, a decision as to desired performance levels is needed, which can be made in consultation with your veterinarian/farm consultant and/or by making comparisons with industry benchmarks.

Following a brief outline of the reproductive biology of pigs, this paper will focus on techniques to fine-tune performance. Specifically, the control of estrus and breeding management will be examined.

REPRODUCTIVE BIOLOGY

An understanding of the estrous cycle is essential before intervention is considered. In simple terms, the 21-day porcine estrous cycle is composed approximately of a 16-day luteal phase and a 5-day follicular phase (I have included a 2-day estrous period in the luteal phase).

- After ovulation, the remains of the ovarian follicles are luteinized to become the progesterone secreting corpora lutea (hence "luteal" phase).

- During the luteal phase, the corpora luteal production of progesterone limits gonadotrophin (LH and FSH) secretion and thus restricts follicular development to the medium follicle stage and prevents the onset of estrus.
- At about 12 to14 days of the luteal phase in the non-pregnant female, uterine production of prostaglandin $F_{2\alpha}$ (PGF) causes regression of corpora lutea and so terminates progesterone production.
- The removal of the progesterone block allows resumption of appropriate secretory patterns of the pituitary gonadotropins, which, in turn, allows ovarian follicular development to be completed (the follicular phase). In weaned sows, the 4 to 5-day wean-to-estrus interval is equivalent to the follicular phase.
- Renewed follicular development produces estrogen, ultimately resulting in behavioral estrus.

Approximately coincident with the onset of estrus there is a surge release of LH which causes a cascade of events within the follicle including a switch from estrogen to progesterone production and culminating with a new ovulation approximately 40 hours after the start of the LH surge.

If the female is successfully bred, embryonic estrogens are produced between about day 11 and 19 of pregnancy. These estrogens constitute the first and second signals for maternal recognition of pregnancy. Other factors are also involved (e.g. LH and PGE), but the net effect is that the PGF is secreted into the uterine lumen rather than into the blood. If the litter is lost after the start of embryonic estrogen production, the result is an irregular return to estrus (25 to 37 days) or possibly pseudopregnancy. Around the time of farrowing, fetal cortisol production initiates the hormonal changes that result in estrogen production, prostaglandin secretion to induce luteolysis, and piglet delivery.

CONTROL OF ESTRUS

Estrus Stimulation

The factor most affecting the predictability of weaner pig output is hitting breeding targets (Dial *et al.*, 1996). Each breeding group is composed primarily of sows having a normal return to estrus after weaning and replacement gilts. The ability to meet breeding targets therefore requires a predictable supply of service ready gilts which is best realized by having them achieve an early puberty. Two methods to stimulate an earlier pubertal estrus are boar exposure and injection of exogenous gonadotrophins.

Boar exposure is the most common practice for inducing early puberty. However, it is important to understand the difference between estrus *stimulation* and estrus *detection*. Adequate stimulation requires direct physical contact while detection may only need fenceline contact (although direct physical contact is better). To maximise efficacy of boar stimulation, follow the rules of boar contact (Kirkwood and Thacker, 1992; Hughes, 1997). The major rules are:

- Gilts must be old enough (ie. at least 150 days of age).
- Boars must be old enough (ie. at least 10 months of age).
- Gilts should be in physical contact with the boar for at least 15 minutes per day.

Fine-tuning boar exposure may involve:

- Taking gilts to the boar and not vice versa.
- Housing gilts at least one meter away from potential stimulus boars. Gilts housed adjacent to boars will be stimulated to an earlier puberty but the estrus detection rate declines. In the event of poor estrus detection management, the use of a separate detection-mating area (DMA) should be considered.
- Performing boar contact twice daily to improve the response.
- Rotating stimulus boars to minimize the potential impact of boars of low stimulus value.
- Ensuring that gilts are not crowded. Allow at least 1.5 m^2 per gilt to prevent delayed puberty and/or reduced estrus detection rates.

When boars are used to stimulate the achievement of the pubertal estrus but gilts are not bred, a regular return to estrus in 18 to 24 days can be expected. However, if the farm protocol is to delay breeding until third or fourth estrus, boar exposure should be allowed every 2 or 3 days to promote regular estrous cycles. In a 100-day test period, the number of estrous periods in boar-exposed gilts was about 5 but, in the absence of boar exposure, gilts averaged only about 3 estrous periods.

If boar exposure appears not to be effective (e.g. a seasonal effect), then a hormonal intervention strategy may be considered. Gonadotrophin treatment (eg. PG600®) is effective for the induction of estrus and ovulation in prepubertal gilts. When hormones are administered, research and clinical experience have demonstrated that up to 30% of treated gilts may ovulate without showing behavioral estrus (Tilton *et al.*, 1992) and about 30% of those having a behavioral estrus may fail to cycle normally (Kirkwood, 1999). Since predictability beyond the induced estrus is not good, gilts should be bred at the induced estrus. A recent study illustrates one outcome of breeding gilts at a gonadotrophin-induced estrus (Table 1).

Table 1. Performance of gilts bred at a PG600®-induced or natural first estrus (lsm ± se).

	Control	PG600	P
Service ready gilts, %	37.5	78.0	0.0001
Service age, d	192.6±6.2	185.9±1.7	0.02
Farrowing rate, %	88.6	74.4	0.01
Litter size (total)	9.7±0.3	9.4±0.3	NS

Kirkwood, 1999.

In sows, wean-to-estrus intervals greater than 5 days are associated with reduced farrowing rates and litter sizes (Wilson and Dewey, 1993; Steverink *et al.*, 1999). The reason for this is unclear but may involve poor synchrony between time of ovulation and time of breeding because these sows will be early ovulators (see below). Therefore, when records indicate a likelihood of frequently delayed estrus (e.g. seasonal or associated with primiparous sows) gonadotrophins can be used to induce a more prompt return to estrus. This hormone treatment will cause more sows to be late ovulators and so also may impact breeding management (see below).

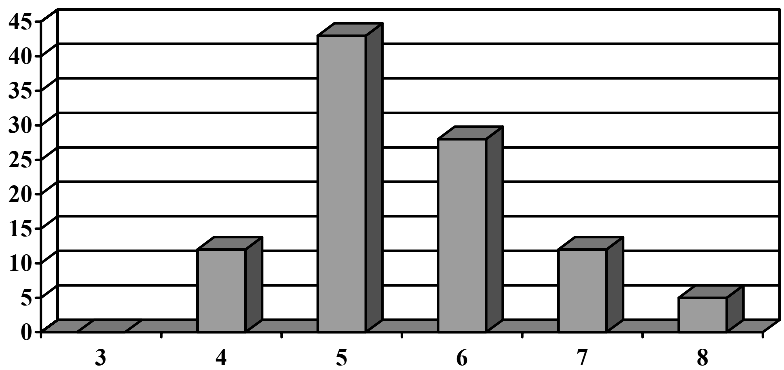
Estrus synchronisation

Depending on how gilts are flowed into the breeding herd, it is possible that there will be a glut of service-ready gilts during one breeding week but too few in other weeks. The challenge is then to control estrus so as to move gilts into another breeding week. If the gilts are prepubertal, injection of PG600 may be effective. If gilts are known to be cyclic, the options for control are limited to breed-and-abort and the feeding of the orally active progestagen, allyl trenbolone (Regumate®). Note that, unlike cattle, a single injection of prostaglandin will not induce luteolysis before day 12 to 14 of the estrous cycle so is of limited value.

For breed-and-abort, the successful establishment of pregnancy results in the endogenous production of progesterone and so blockade of estrus until pregnancy is terminated. Pregnancy can be terminated at any time prior to term and the gilt or sow should return to estrus 5 to 6 days later (but may be as long as 10 days). However, at some stage during pregnancy a requirement for uterine involution will likely become an issue such that, while a female may return to estrus, incomplete uterine involution may limit subsequent litter size. Also, terminating pregnancy after 25 to 30 days may raise ethical and esthetic issues. If undertaken, terminate pregnancy 25 to 30 days post breeding with a split dose of prostaglandin (e.g. half dose intravulvally in the morning and again 6 to 8 hours later). Females returning 5 to 6 days later had normal fertility (Pressing *et al.*, 1987).

The feeding of Regumate is an effective means of controlling estrus (Foxcroft *et al.*, 1998). While being fed, Regumate does not prevent normal luteolysis but will maintain the block on estrus onset after luteolysis occurs. In effect, the luteal phase is being artificially prolonged. Ideally, gilts should be individually fed so that they consume at least 15 mg/d. While there is likely no problem with overdosing (except economic), underdosing Regumate (<13 mg/d) will likely cause cystic follicles (Davis *et al.*, 1979; Kraeling *et al.*, 1981). If fed appropriately, expect 90 to 95% of gilts to exhibit estrus on days 4 to 8 after last feeding (Figure 1). Fine-tuning the feeding of Regumate is possible. Since Regumate needs to be fed only from luteolysis, if cycle dates are known you can minimize Regumate feeding by only providing it from day 12 to 14 of the estrous cycle until 5 days before gilts are scheduled to be bred.

Figure 1. Timing of return to estrus after Regumate® withdrawal in gilts (data from University of Alberta).



Regumate can also be fed to sows from weaning and the estrus response following withdrawal is the same as for gilts. Note that the first Regumate feeding must be on the day of weaning. The synchronised wean-to-estrus interval will be longer, but predictably so. Also, feeding Regumate for 7-days after weaning improved litter size of primiparous sows (Kirkwood *et al.*, 1986). Presumably, the feeding of Regumate captured the effect of skip-a-heat breeding but with fewer non-productive sow days. Further, where early weaning is practiced and is believed to be affecting sow fertility, delaying the post weaning estrus with Regumate permits sows to have a longer recovery period and will likely improve sow fertility (Table 2).

Table 2. Effect of a 12-day lactation followed by 12-day Regumate feeding on primiparous sow performance.

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

Koutsotheodorus *et al.*, 1998

BREEDING MANAGEMENT

Semen backflow

The basic principles of artificial insemination are simple; place enough viable sperm in the right place at the right time, and keep it clean. Using current insemination technology, 3×10^9 sperm are deposited in the cervix. This large number is necessary because most of the sperm will either be lost due to back-flow of semen, as well as entrapment and death in the cervix and uterus (Steverink *et al.*, 1998). When backflow was considered to be excessive during insemination, sow fertility was reduced. Therefore, fine-tuning AI technique aims to minimize semen backflow. The most obvious components of AI to assess are catheter placement and whether semen is being forced through the AI catheter. If backflow is excessive, insufficient sperm will remain in the sow, fertilization rate will be compromised, and an increased regular return rate will be observed.

Sperm transport

In reality, it is not the number of sperm deposited in the cervix or uterus that ultimately controls fertility, it is the number of sperm that enter the oviduct that is important. The proportion of inseminated sperm that actually get to the oviduct is variable, but 2% is a reasonable figure. The sperm in the oviduct enter an arrested state and constitute the sperm reservoir potentially available to fertilise ova. In order to reach the oviduct, the sperm must traverse about 1 meter of uterus and get through the junction of the uterus and oviduct (uterotubal junction or UTJ). This sperm transport is performed by uterine contractions. Most estrous sows will have some spontaneous uterine contractility, which is improved by boar stimuli. If uterine contractions are reduced (e.g. if the boar is not present), sperm transport will be poor, the sperm reservoir reduced, and fertility lowered. Uterine contractility cannot be monitored on-farm so fine-tuning sperm transport involves implementing techniques known to enhance uterine contractility. The key to good uterine contractility is stimulation of the sow during and after insemination. Aim for 10 min of boar contact after insemination. If the boar has to be moved, have a second boar come behind him to continue the stimulation. If boar power is limited, use a stink-stick. For this, a rag soaked in preputial fluid and a very little urine is tied to a stick and left to hang over the sow's head. If a breeding belt or other similar accessory is employed, do not remove it for about 10 min. Remember, once the semen dose has been taken up by the sow, a lot of the sperm are in the body of the uterus and still need to be transported towards the oviducts.

Hormones can also be used to stimulate sperm transport. The rationale is that the hormonal content of natural seminal plasma has a functional role and the absence of these hormones from extended semen may be involved in performance depression on some farms (e.g. start-ups). In support of this suggestion, previous work has shown that reproductive performance may be improved with the addition of estrogen or oxytocin to extended semen (Kirkwood and Thacker, 1991; Pena *et al.*, 1997), or injection of oxytocin or PGF at the time of insemination (Flowers, 1996; Pena *et al.*, 1998). The effect of these hormones is to increase uterine contraction and so improve sperm transport (Claus *et al.*, 1989). Although oxytocin is very inexpensive, and therefore cost-effective, its routine use should be recommended with care. Contractions may be excessive and so increase sperm backflow resulting in reduced fertility. When breedings are performed by well-trained personnel there is likely to be little benefit from the use of hormones. Therefore, the use of hormonal adjuncts at breeding is likely covering up inadequate breeding management. While this may be acceptable during the transition period of adoption of artificial insemination, long-term performance is best achieved by appropriate training of personnel.

After deposition into the female, sperm have to undergo the process of capacitation before they can fertilise an egg. Once started, this process takes about 6 hours to complete. Capacitation is a "one-way street" at the end of which the sperm must either fertilise an egg or die. However, fresh sperm are non-capacitated and so can attach to the epithelium near the UTJ, and enter the arrested state that slows (but does not stop) their attrition. Signals arriving near the time of ovulation cause the release of sperm from their arrested state and allow them to redistribute along the oviduct towards the site of fertilisation (isthmus-ampulla junction) and to complete capacitation. The number of functional sperm available for fertilisation (which will impact sow fertility) will be dependent on the number originally entering the sperm reservoir (which is influenced by sperm transport) and the interval between sperm entry to the reservoir and their redistribution at the time ovulation (which is influenced by timing of insemination relative to ovulation).

Timing of insemination

Sow fertility following AI (i.e. fertilisation rate, farrowing rate, litter size) depends on the time of insemination relative to ovulation (Kemp and Soede, 1996). If insemination occurs at or soon after the time of ovulation, by the time capacitation has occurred the eggs may be too old. Late inseminations are also associated with an increased risk of urogenital disease and reduced sow performance (Rozeboom *et al.*, 1997; Tarocco and Kirkwood, 2001). If inseminated too far in advance of ovulation, too many sperm capacitate and die before ovulation occurs. The result is the same as inseminating too few sperm to begin with. To maximise fertility, deposition of fresh-extended semen into the sow should occur during the 24-hours before ovulation (Table 3).

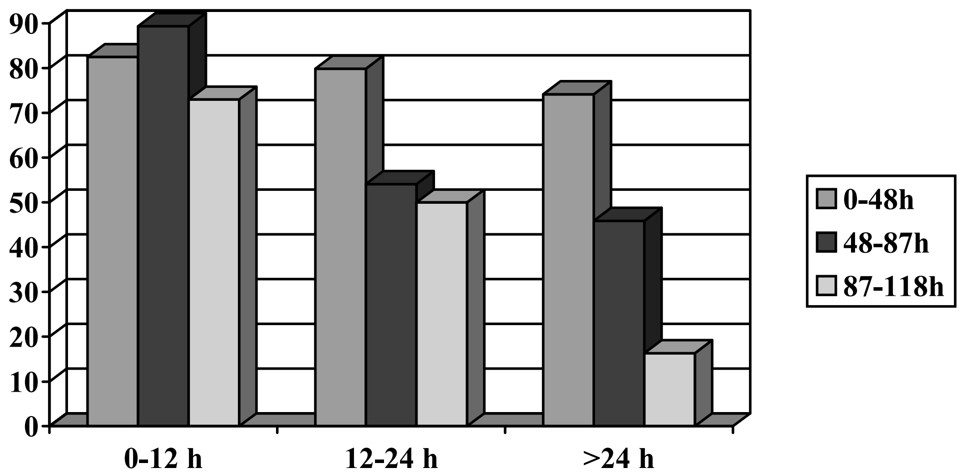
Table 3. Effect of insemination to ovulation interval on sow fertility.

	Farrowing rate, %	Litter size
Before ovulation		
24-36 h	68	11.8
0-24 h	92	13.2
After ovulation		
0-12 h	76	12.3

Nissen *et al.*, 1997

Assuming good quality semen, inseminations need only be performed every 24 hours. However, if the sperm are not fully viable (e.g. >48-days since collection), more frequent inseminations may be beneficial because sperm viability may be reduced (Figure 2). Presumably, the effect of aged semen is that the number of viable sperm in the sperm reservoir is too low. Therefore, performing am/pm breedings will "top up" the sperm reservoir.

Figure 2. Effect of semen age and time of ovulation on fertilization rate (Waberski et. al. 1994).



The time from detection of estrus to ovulation is variable (Figure 3). In this data set 7-19% of sows ovulated by 24 hours after detection of estrus (early ovulators). Unless still showing a good standing estrus, females ovulating by 24 hours after estrus detection should not be bred on day 2. Although the exact figure is going to depend on the assessment of each farms estrus detection management and expertise, it is reasonable to suggest that about 10% of females will be early ovulators. Single mating of these animals is not a problem since it almost guarantees that they will be bred during the 24-hour window before ovulation. However, if too many females receive a single breeding (e.g. more than 15%), detection of estrus onset is probably inadequate. Further, if too few females receive a single breeding (e.g. less than 5%) it is probable that some early ovulators are being bred in late estrus (or possibly diestrus). Using the same data sets, 20-25% of females will ovulate more than 48 hours after the detection of estrus onset (late ovulators). Breeding of these females on day 3 of estrus is not a problem. Indeed, limited field data showed a 6% increase in overall farrowing rate when these sows are bred (G. Ludvigsen, personal communication). So, if the breeding records show few if any third-day breeding, it is possible that some females are being bred too early. Alternatively, greater than 25% third-day breeding indicates that some females are being bred too late.

Timing of ovulation

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

Figure 3. Interval from estrus onset to ovulation in sows.

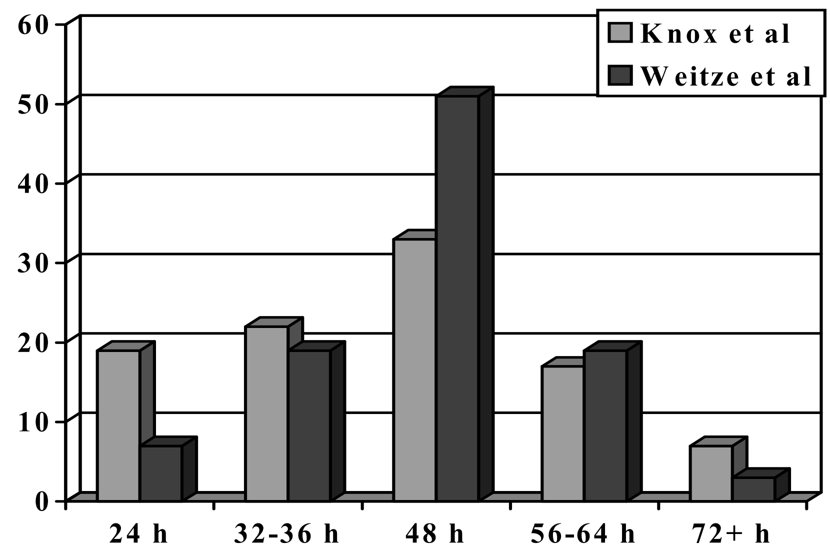


Table 4. Effect of wean-to-estrus interval (WEI) on estrus-to-ovulation interval.

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

Kemp and Soede, 1996.

In commercial practice, it is often observed that the fertility of sows inseminated following a wean-to-estrus interval of 6 or more days is less than for sows inseminated following shorter wean-to-estrus intervals (Vesseur *et al.*, 1994; Steverink *et al.*, 1999). The etiology of this effect is unknown but, given that these sows will likely be early ovulators, it may involve the timing of insemination relative to ovulation in these sows. Indeed, with once-daily estrus detection, some sows may already have ovulated when estrus is first detected. A component of the interval between insemination and fertilisation is the approximately 6 hours required for capacitation of the sperm. The effect of this is that when a short interval between sperm deposition and fertilisation capability is required, such as following insemination at about the same time as ovulation, the time required for capacitation may be a factor in the resultant poor fertility. To reduce the effect of early ovulation, sows not detected in estrus by 5 days after weaning should be heat-checked at least twice daily to more accurately detect onset of estrus. A further method for reducing the impact of long wean-to-estrus intervals is to shorten the interval by the injection of gonadotrophins (e.g. PG600). If this is done, appreciate that using hormones will create late ovulating sows (Knox *et al.*, 2001) and many of these sows will require a day-3 breeding.

Housing pregnant sows

There is a growing impetus to group house sows, for both welfare perceptions and economics. However, with large groups of sows, individual housing for estrus detection and breeding is still the method of choice. When this is done, at some point the females will need to be mixed. The safest time to mix bred sows, in terms of maintenance of pregnancy, remains to be determined. However, based on zero evidence, the concensus is that if sows are to be mixed, it should be done between 1 and 3 days after the final insemination (i.e. before the conceptus arrives in the uterus) or from 28 days after the final insemination (i.e. after placentation is complete). When sow groups are formed, the inclusion of a mature boar in the group may reduce aggression between sows.

An alternative is to create groups at weaning. This minimises the effect of aggression on pregnancy maintenance but estrus detection and breeding become more difficult. It is possible that, if electronic feeders are employed, the transponders could be used to monitor sow traffic to boars housed adjacent to the sow pen. Proestrous and estrous sows will spend much more time in the vicinity of the boars. Once identified, sows can be moved to a detection-mating area for insemination and then returned to the group.

Induction of farrowing

The ability to predict times of farrowing allows for ease of supervision of farrowing, which in turn can potentially save 0.5 pigs per litter. Before employing farrowing induction, calculate the average gestation length for the individual herd from at least the previous 100 gestations. Do not induce more than 2-days before due date. To induce the sow, inject prostaglandin in the morning and again in the afternoon. Use the full-recommended dose if injecting intramuscularly, or half dose if injecting into the vulva. If there is a history of savaging, consider treating all gilts with an intramuscular injection of corticosteroid when signs of impending delivery become evident.

CONCLUSIONS

Fine-tuning control of estrus in gilts should involve a critical assessment of boar exposure technique. If performed appropriately and further control of estrus is required (e.g., better synchrony), hormones can be employed to either stimulate onset of estrus or to suppress estrus until required for breeding. In sows, estrus suppression can be employed to allow sows a longer recovery period after weaning which likely will result in improved fertility.

Fine-tuning of breeding management involves critically assessing insemination techniques to minimise semen backflow. Also, insemination in the 24-hours before ovulation is important. Therefore, inseminations should be performed at 24-hour intervals but only if the females are exhibiting strong signs of estrus. Twice daily inseminations should be considered when semen age exceeds 48-hours. To reduce the potential for late insemination of early ovulators, sows not showing estrus by day 5 should be heat-checked twice daily and inseminated immediately.

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CHANGING PRODUCTION PRACTICES

CHANGES IN THE MIDWESTERN U.S. PORK INDUSTRY

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ABSTRACT

Midwest pork production has changed dramatically in the past ten years and continues to evolve. This traditional home of US hog production had the most to lose and was perhaps the slowest to change because of its long-standing dominance and culture. Part way through the 1990s, production companies began to apply emerging production technologies used in other regions in the Midwest. All states in the region lost breeding herd numbers, but Iowa and Minnesota increased the number of market hogs. The eastern part of the region experienced a greater loss of hogs and farms than did the western states evaluated. At least a portion of the difference in inventory changes is due to existence of large-scale producers in the state. Marketing methods also changed dramatically. While still the prominent place of price discovery, trading several thousand hogs a day, the percent of hogs negotiated in the daily market stands at less than 20 percent.

INTRODUCTION

The global pork industry has changed dramatically in the last 10 years and perhaps no place is the change more apparent than in the "hog belt" of the US. The Midwest traditionally produced the majority of US hogs. During the 1980s, nine Midwestern states accounted for approximately 71 percent of the nation's breeding herd and 72 percent of the market hog inventory. Today these same states have 57 percent of the US breeding herd and 63 percent of the market hogs. The regional shift was driven by, or at least in conjunction with, a consolidation in the sector. In 1982, there were 197,500 farms with hogs that had an average inventory of 199 head per farm. By 2002, the number of farms had declined to 36,000 with an average inventory of 1026 head.

Declining profitability in pork production is one driving force. The estimated returns to farrow to finish operations for the five-years 1980-1984 averaged $13.99, and averaged $7.30 for the five-years 1998-2002. While gross margins over feed costs on 400 hogs marketed a year (199 head inventory turned twice a year) would have made a significant contribution to family income in 1980, there may be little margin left after feed and direct costs and debt service today. Another significant change in Midwest hog production is marketing methods. As recently as 1993, 87 percent of US hogs were purchased in the cash market. Today that number is approximately 17 percent as nearly two-thirds of hogs are sold through marketing contracts and packers own an estimated 18 percent of the hogs.

CHANGING DEMOGRAPHICS

The Midwest's advantage in hog production is its relatively low feed costs. Thus, it is no surprise that the breeding herd inventory has declined faster than the market hog inventory. The breeding herd in the nine states dropped nearly 1.6 million head in 10 years, a 32 percent decline from 1993 (Table 1). Iowa and the eastern states (IL, MI, IN, and WS) declined 38 and 40 percent, respectively while the western states (MN, MO, NE, and SD) declined only 19 percent. It should be noted that the US breeding herd declined 16 percent over the same period, so the four western states basically maintained their share of the US sow herd, but Iowa and the four eastern states lost their share. In total, these Midwestern states went from having 70 percent of the nation's breeding herd to only 57 percent by the end of 2002.

Table 1. December Breeding Herd Inventories for Selected Midwestern States (1,000s).

	Iowa	ILMIINWS	MNMONESD	MW Total	US Share
1993	1,700	1,525	1,780	5,005	70%
1994	1,500	1,455	1,750	4,705	67%
1995	1,350	1,285	1,715	4,350	64%
1996	1,250	1,225	1,595	4,070	61%
1997	1,360	1,245	1,690	4,295	62%
1998	1,260	1,185	1,570	4,015	60%
1999	1,160	975	1,480	3,615	58%
2000	1,120	1,010	1,480	3,610	58%
2001	1,130	965	1,465	3,560	57%
2002	1,050	920	1,445	3,415	57%

ILMIINWS: Illinois, Michigan, Indiana, Wisconsin
MNMONESD: Minnesota, Missouri, Nebraska, South Dakota

Iowa has 1.05 million animals in the 2002 breeding herd, 5,000 more than the second largest hog producing state, North Carolina. North Carolina's breeding herd increased from approximately 300,000 head during the early 1980s to 625,000 in 1993, to 1 million in 1996 where it has remained. The breeding herd has also increased in "non-traditional" states such as Oklahoma (+180,000 sows, 300 percent increase), Colorado (+85,000 sows, 113 percent increase), Texas (+40,000, 62 percent increase) and Utah (+30,000, 600 percent increase) as production companies found that these arid regions had fewer hogs and fewer neighbors. These four states added 325,000 breeding animals in 10 years.

The number of market hogs in the Midwest has not changed as dramatically as the breeding herd has. The market hog inventory in these nine Midwest states declined 2.4 million head over the 10 years or about 7 percent (Table 2). However, there are differences within the region. Iowa increased its market hog inventory 950,000 head (7 percent) while the four eastern states decreased 2.9 million head (28 percent). The remaining four western states saw a 425,000 (4 percent) decline. The regional share of the US market hog inventory fell from 71 to 63 percent. Corn prices are cheaper as you move west across the Midwest with the lowest prices near the corner of Iowa, Minnesota, and South Dakota. There remains excess packer capacity in Iowa providing strong demand for hogs.

Although not as dramatic as the increase in sow farms, finishing has increased outside the Corn Belt. North Carolina's market hog inventory increased 80 percent, 3.825 million head in 10 years. A new Smithfield processing plant that opened in 1998 facilitated this growth. Other "new" states have also increased finishing inventory: Texas, up 325,000 or 90 percent, Colorado, up 255,000 or 68 percent, and Oklahoma up 1.83 million or more than a 500 percent increase. A new plant was opened in the Panhandle of Oklahoma in the late 1990s as this production came on line.

Table 2. December Market Hog Inventories for Selected Midwestern States (1,000s).

	Iowa	ILMIINWS	MNMONESD	MW Total	US Share
1993	13,300	10,595	12,020	35,915	71%
1994	13,000	10,685	12,690	36,375	69%
1995	12,050	9,595	12,335	33,980	66%
1996	10,950	8,725	11,555	31,230	63%
1997	13,240	9,165	12,460	34,865	64%
1998	14,040	9,525	12,230	35,795	64%
1999	14,240	7,925	11,430	33,595	63%
2000	13,980	8,050	11,590	33,620	64%
2001	13,870	7,935	11,315	33,120	63%
2002	14,250	7,660	11,595	33,505	63%

ILMIINWS: Illinois, Michigan, Indiana, Wisconsin
MNMONESD: Minnesota, Missouri, Nebraska, South Dakota

The one place where the Midwest has not lost its share of the US pork industry is in the number of farms with hogs. Farms with hogs declined 70 percent in these states from 1993 to 2002 (Table 3). Table 4 shows the average number of hogs per farm and shows the trend to larger farms. Iowa farm size increased by three-fold as have the farms in the four western states. The farms in the eastern states doubled in size.

Iowa's finishing inventory dropped sharply before rebuilding to record levels. In 1996, during record high corn prices and in the midst of a pronounced change in industry structure, market hog inventories declined to less than 11 million head. By 1999, inventories had grown nearly 3.3 million head to 14.24 million. Although difficult to quantify, there has been significant reinvestment in finishing space in Iowa between 1993 when contract production was first beginning and double curtain-sided barns were introduced. Iowa has retired older facilities that ranged from outdoor earthen lots, Cargill-style open lots, to Modified Open Front facilities built in the 1970s. Today the majority of hogs are finished in double curtain-sided barns typically with 900-1200 head capacity built 2-4 buildings per site. These buildings have either deep-pit or external formed storage and the bulk of the manure is injected in nearby fields with some transported to fields as much as 6-8 miles away. This model is still being built today with relatively little resistance from neighbors (there are exceptions).

Table 3. Number of Farms with Hogs for Selected Midwestern States.

	Iowa	ILMIINWS	MNMONESD	Total	US Share
1993	33,000	37,100	43,800	113,900	51%
1994	29,000	34,800	42,000	105,800	51%
1995	25,000	30,100	35,900	91,000	50%
1996	21,000	26,400	29,500	76,900	49%
1997	18,000	22,500	24,000	64,500	53%
1998	17,500	19,500	22,600	59,600	52%
1999	14,500	18,000	19,200	51,700	53%
2000	12,300	14,700	16,800	43,800	51%
2001	10,500	15,000	14,600	40,100	49%
2002	10,000	12,600	13,400	36,000	48%

ILMIINWS: Illinois, Michigan, Indiana, Wisconsin
MNMONESD: Minnesota, Missouri, Nebraska, South Dakota

Table 4. Average Number of Hogs per Farm in Selected Midwestern States.

	Iowa	ILMIINWS	MNMONESD	Total
1993	455	327	315	359
1994	500	349	344	388
1995	536	361	391	421
1996	581	377	446	459
1997	811	463	590	607
1998	874	549	611	668
1999	1,062	494	672	720
2000	1,228	616	778	850
2001	1,429	593	875	915
2002	1,530	681	973	1,026

The eastern states declined in market hog inventory and smaller average inventory reflects the loss of small farms, but with less reinvestment in new finishing facilities. Each of the four states had losses of 24-54 percent of their market hog inventory. There are vast differences in changes in market hogs inventories within the four western states. From 1993 to 2002 Missouri's numbers were basically unchanged, +1 percent. Minnesota increased 28 percent (1.16 million head) while Nebraska and South Dakota declined 33 and 25 percent, respectively (1.225 and 0.385 million head, respectively). Table 5 is the distribution of hog inventory by size of operation. Iowa and the western states tend to have more inventory on farms, with more than 5000 head, than do the four eastern states.

Much of the difference in state market hog inventories can be related to the existence of large operations. Iowa has several of the 40 largest pork producers finishing hogs in the state (Freese 2002). Minnesota and Missouri also have some of the largest producers. The breeding herd losses in the Midwest would have been larger without investment by these larger firms in the region. National, or international, firms can choose where to produce and the relative feed costs and packer capacity in the region likely influenced their decision.

Table 5. Percent of Hog Inventory by Size of Operation, Selected States, December 2003.

Head	Under 1000	1000-1999	2000-4999	5000+
IA	13.7	17.3	26.0	43.0
MN	16.0	15.0	25.0	44.0
SD	21.0	11.0	21.0	47.0
NE	21.8	15.2	21.0	42.0
MO	11.0	4.0	20.0	65.0
IL	18.0	19.0	30.0	33.0
IN	15.5	17.5	29.0	38.0
MI	15.0	12.0	34.0	39.0
WS	40.0	25.0	22.0	13.0

CHANGING MARKET COORDINATION

Methods of hog marketing have changed dramatically over the last 10 years. In 1993, 87 percent of U.S. hogs were sold in the spot market, 2 percent were owned by packers and the remaining 11 percent were purchased on contract (Hayenga *et al.*, 1996). Table 6 shows the recent trend in hog procurement. By early 2002 the percent of hogs in the cash market declined to less than 17 percent. At the same time packers owned over 18 percent of hogs with a portion of these sold to other packers. Marketing contracts accounted for the remaining 65 percent of the hogs. Hog marketing contracts between producers and packers are typically 3-10 years in length or perpetually renewing, and clearly establish a long-term relationship regarding delivery schedules, carcass specifications, and quality assurance.

Table 6. Percent of U.S. Hogs Sold Through Various Pricing Arrangements, January 1999-2002.*

	1999	2000	2001	2002
Hog or meat market formula	44.2	47.2	54	44.5
Other market formula	13.2	20.8	21.9	11.8
Other purchase arrangement	4.6	4.6	6.6	8.6
Packer-sold				2.1
Packer-owned				16.4
Negotiated – spot	35.8	25.7	17.3	16.7

*2002 data based on USDA Mandatory Reports, 1999-2001 based on industry survey by University of Missouri and National Pork Board

While there are significantly fewer hogs in the cash market today than 10 years ago, there are still several thousand hogs a day traded. USDA Mandatory Price Reporting (MPR) indicated the number of hogs purchased and slaughtered daily by procurement method. Table 7 is a snapshot of the Iowa Southern Minnesota market during the third week of January 2003. The report is of "Purchased Swine" meaning the hogs that were bought that day to be slaughtered some time within the next seven days. Note that between 15,000-28,000 hogs traded each day that week when the total volume was in the 120,000 - 140,000 range, approximately 14 percent for the week. The larger numbers on Friday may reflect Saturday purchases. Iowa does not allow packers to own hogs and thus there is no report of packer owned hogs in the Iowa report. . (This Iowa law was found unconstitutional in recent court case. The state plans an appeal.)

Table 7. Iowa Southern Minnesota Barrows and Gilts Prior Day Purchased Swine Volume.

Date	Negotiated	Other Market Formula	Swine/pork Market Formula	Other Purchase Agreement
01/20/03	20,141	6,672	72,667	38,202
01/21/03	22,176	9,716	66,144	21,731
01/22/03	15,859	5,150	68,215	17,761
01/23/03	17,374	7,607	65,085	16,289
01/24/03	28,505	43,330	77,594	116,539

Table 8 is a summary of the national report of hogs slaughtered the previous day by procurement method. The number of negotiated hogs in the national report was approximately 13 percent of the hogs covered under MPR. Packers that slaughter less than 125,000 hogs annually do not have to report and this accounted for the additional hogs reported in the Federally Inspected Slaughter that were not reported in MPR for the same week. Packers owned more hogs than they bought in the cash market.

Table 8. National Daily Direct Hog Prior Day Report - Slaughtered Swine Barrows and Gilts.

Date	Negotiated	Other Market Formula	Swine/pork Market Formula	Other Purchase Agreement	Packer Sold	Packer Owned	Total MPR Count
01/20/03	44,123	19,411	133,025	66,594	4,730	60,023	327,906
01/21/03	42,716	19,626	143,100	62,089	9,883	64,049	341,463
01/22/03	46,519	25,114	143,361	70,165	8,390	57,427	350,976
01/23/03	39,106	19,230	125,898	68,773	6,538	55,891	315,436
01/24/03	57,891	19,185	145,819	83,138	8,999	67,442	382,474

As noted earlier, most hogs trade on a formula. The largest category is the Swine/Pork Market Formula which represents hogs purchased on a formula tied to the cash market for hogs or wholesale pork. The Other Market Formula are hogs bought on a formula based on some market other than hogs and pork, typically feed prices. The Other Purchase Agreement category is a bit of a catch-all, but includes window contract purchases.

While there is legislation introduced in Congress to prohibit packer ownership of livestock and force them to buy a minimum number of hogs in the open market, marketing contracts will likely continue. Both producers and packers have identified positive aspects of marketing contracts. Pork producers identified price level and price risk as the two greatest advantages to having a marketing contract. Two potential concerns about contracts—being locked out of higher prices and not being treated fairly by packer—were considered unimportant by producers in a recent survey (Lawrence and Grimes, 2001).

Packers' primary motivations for the use of long-term marketing agreements are their need for a consistent supply of quality animals and higher quality animals to meet consumer demand. They expect these reasons to be even more important in the future (Hayenga, *et al.* 2000). In addition to quality traits that impact eating experience, consumers value food safety and the ability to trace product to the point of origin. In some, but not all, cases the processor or retailer is willing to pay for the additional cost of certain food safety measures in order to reduce their liability (Lawrence and Hayenga, 2002).

Changes in hog marketing methods have introduced market access concerns to many Midwest pork producers. Larger producers more readily use these new marketing arrangements (Lawrence and Grimes, 2001). Seventy-five percent of the farms selling less than 3,000 hogs per year sold their hogs in the cash market. Farms selling 3,000-10,000 and 10,000-50,000 hogs a year sold 55 and 40 percent, respectively in the cash market. Those marketing 50-500,000 hogs a year sold 10 percent in the cash market and farms selling over a half a million head annually sold only one percent of their hogs in the cash market.

CONCLUSIONS

Midwest pork production has changed dramatically in the past ten years and continues to evolve. This traditional home of US hog production had the most to lose and was perhaps the slowest to change because of its long-standing dominance and culture. Production companies began to apply emerging production technologies used in other regions in the Midwest beginning in the mid-1990s. All states in the region lost breeding herd numbers, but Iowa and Minnesota increased the number of market hogs. The eastern part of the region experienced a greater loss of hogs and farms than did the western states evaluated. At least a portion of the difference in inventory changes is due to existence of large-scale producers in the state.

A concern of producers that have marketing contracts is that of accurate price discovery. Many of the Swine/Pork Market Formula and Other Market Agreement contracts are based on the price "discovered" by Negotiated transactions. The producers in these contracts have entered the contract to avoid the cash market, but hope that the producers still in the cash market are aggressive negotiators and extract a good price for their hogs.

Minnesota is worthy of further discussion. It had only a 2 percent decline in breeding herd inventory compared to a 38 percent drop in Iowa and 16 percent decline for the nation as a whole between 1993 to 2002. Minnesota also increased market hog inventory 28 percent, 1.16 million head, the largest increase in the nine states. What is unique about Minnesota's success is that it has largely come from within. Of the nine companies on the US top 40 largest producers list operating in Minnesota, 5 are Minnesota based companies and at least one is farmer network with multiple farmer owners under a common management. Other states have natives' sons and daughters that have grown, but few of the local firms are as large a part of the state's sector as is the case in Minnesota.

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LIQUID FEEDING AS A MEANS TO PROMOTE PIG HEALTH

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ABSTRACT

Surveillance studies have shown that liquid feeding of pigs reduces the incidence of salmonella. This has been particularly associated with the use of acidic residues derived from the food industry. More recently, and particularly because producers wish to feed liquid diets *ad libitum*, there has been much interest in the concept of feeding fermented liquid feed (FLF) to pigs. Natural, uncontrolled fermentation has produced very mixed results on commercial units. However, when selected lactic acid bacteria inoculants are used and fermentation conditions are carefully controlled, an acidic diet is produced that rapidly and effectively excludes enteropathogens.

When diets are produced by controlled fermentation they are readily accepted by pigs. Such feed has been shown to enhance post-weaning growth and reduce coliform levels in the lower gut. Because of this, FLF may be a useful alternative to antibiotic growth promoters and avoid the problems associated with the development of antibiotic resistance. Although results in experimental units are impressive, more research is needed before we can provide Standard Operating Procedures relevant to different conditions. These are needed to enable the transfer of this exciting technology to commercial pig units.

INTRODUCTION

It is important to define liquid feeding and differentiate it from other feeding systems. Liquid feeding involves the use of a diet prepared either from a mixture of liquid food industry co-products and conventional dry components, or from dry raw materials mixed with water. Generally, the diets are mixed at a central point on the pig unit. If the pigs are ration-fed, a single pipeline can be used to transfer the mixed feed direct to target pigs, wherever on the unit they may be. If the pigs are to be fed *ad libitum* the feed is often moved to 'satellite' tanks, from which specific groups of pigs are fed. Thus in a modern system, one feed preparation area can produce a range of diets to match the nutrient requirements of pigs of different ages and stages of production.

A liquid diet will typically contain 200-300 g dry matter (or dry ingredients) per kg. This type of feeding system should not be confused with wet/dry feeder systems where water and feed are kept separate up to the point of delivery to the pig. A key difference between these two feeding systems is the length of time that the dry matter fraction of the diet is in a liquid medium before it is consumed by the pig. This has important implications for the microbiology of, and nutrient availability from, the feed.

POTENTIAL ADVANTAGES OF LIQUID FEEDING

Traditionally, producers have perceived a number of advantages in using liquid feeding. These include:

- Reduction of food loss, as dust, during handling and feeding.
- Improvement in the pigs' environment and health due to the reduction of dust in the atmosphere.
- Improved pig performance and feed conversion ratio (FCR).
- Flexibility in raw material use (opportunity to utilize more economic food sources and reduce cost per kg gain).
- Improved materials handling (system can act as both a feed mixing and distribution system).
- Increased accuracy of rationing (computer control brings a degree of accuracy to the system that it is difficult to emulate with dry feeding systems).
- Improved dry matter intake in problem groups (e.g. weaners and lactating sows).
- Improved intakes at high ambient temperatures.

Jensen and Mikkelsen (1998) reviewed nine recent studies in which the performance of pigs fed dry or liquid diets were compared (Table 1). Grow-finish pigs fed liquid diets generally had improved daily live-weight gain and feed conversion ratio.

Table 1. Improvement (%) in growth rate and feed conversion ratio in nine experiments conducted to compare liquid and dry feeding for grow-finish pigs (Jensen et al. 1998).

Improved daily weight gain		Improved feed conversion ratio	
Mean ± SD	Range	Mean ± SD	Range
4.4 ± 5.4	-2.6 - 15.0	6.9 ± 3.5	1.9 - 12.7

To this improved performance must now be added other benefits that can accrue to the environment through:

- The utilization of co-products from the human food industry which would otherwise incur a cost for environmentally acceptable disposal
- Reduction in nitrogen loading through the easy adoption of 'step' and 'phase feeding'
- Reduction in phosphate loading through activation of endogenous phytase in cereal grains and / or the addition of exogenous enzymes to diets.

The latter are outside the scope of this paper and will not be discussed further.

UTILISATION OF LIQUID HUMAN FOOD INDUSTRY CO-PRODUCTS

In discussing the potential health benefits of liquid feed it is appropriate to consider the use of food industry liquid co-products, as these play an important role in the maintenance of animal health on many units. This aspect will be discussed in the next section.

Liquid co-products of many sorts are used for pig feeding around the world. However, we should look to The Netherlands for the best example of co-product utilization. In The Netherlands, it has been estimated that about 6.5 million tonnes of co-products are used annually on farms (de Haas 1998). The quantity of material has increased dramatically in recent years and it is predicted that it will continue to increase. Currently, demand exceeds supply and consequently, co-products are being shipped into The Netherlands from France, Poland and even the UK. Of the 6.5 million tonne total, approximately 35% (2.3 million tonnes) is fed to pigs (Table 2). Of this, 70% consists of carbohydrate rich materials (Scholten *et al.* 1999). The importance of these co-products to pig production is put into perspective when it is remembered that the net production of pork in The Netherlands in 1996 was 1.62 million tonnes (Meat and Livestock Commission 1998). Such detailed data are not available from other countries, but using information from trade sources we estimate that approximately 30% of pigs in Northern and Western Europe are fed liquid diets and a majority of these incorporate at least some food industry co-products.

Table 2. Amount of liquid co-products (tonnes) from the food industry delivered directly to pig farms in the Netherlands (Scholten et al. 1999).

Product	1993	1996
Wheat starch industry	650,000	885,000
Potato processing industry	350,000	525,000
Dairy industry	300,000	300,000
Fermentation industry	80,000	120,000
Beer industry	80,000	100,000
Sugar industry	25,000	50,000
Other	170,000	360,000
Total amount (tonnes)	1,655,000	2,340,000

A major problem for the nutritionist and the pig producer wishing to use co-products is the variability in their composition (Table 3). This means that if they are going to be used efficiently diets have to be continually reformulated to compensate for the changes in composition that can occur from one load to the next.

Despite the variability of liquid products, they can be used efficiently and without detriment to pig performance if diets are formulated accurately. For example, Scholten *et al*. (1997) used combinations of liquid wheat starch, liquid potato steam peelings and cheese whey to replace 35% of the dry matter in growing pig diets and 55% in finishing diets at a water to feed ratio of 2.6:1. The results of their study (Table 4) show that, when the diet is properly balanced, the inclusion of co-products does not adversely affect pig performance.

In a recent study 'wheat bottom stills' (Greenwich Gold™), a residue left after the production of ethanol, was substituted in diets for grow-finish pigs (Table 5). The basal diet was a conventional UK diet based on wheat and barley with extracted soyabean and rapeseed as the principle protein sources and substitutions were made using best-cost formulation. The growth rate and carcass quality of pigs was not affected by substituting conventional raw materials with up to 30% of this co-product (Brooks *et al.* 2001).

Table 3. Variability in composition of some feed components (Brooks et al. 1995).

		Dry matter ($g\ kg^{-1}$)	Crude protein ($g\ kg^{-1}$ DM)	DE ($MJ\ kg^{-1}$ DM)
Liquid Products	Yoghurt	22 – 191	139 - 389	17.3 – 21.8
	Whey	20 – 58	115 - 234	13.4 – 15.9
	Delactosed whey	210 – 406	206 - 293	6.8 – 15.1
	Milk	126 - 193	211 - 396	14.6 – 24.3
	Wheat bottom stills (a)	155 – 193	207 - 258	12.6 – 17.2
	Wheat bottom stills (b)	76 – 160	192 - 367	13.9 – 16.3
	'C' starch	133 – 159	68 - 106	15.6 – 16.2
	Poultry processing residue	84 – 239	211 – 364	16.2 – 23.5
Dry Products	Biscuit meal	87 – 95	76 – 126	15.4 – 17.9
	Wheatfeed	87 – 89	152 – 187	12.4 – 13.1
	Maize gluten	87 – 90	203 – 227	12.7 – 13.1
	Hi-pro Soya bean meal	87 – 90	421- 514	12.9 – 16.2

Table 4. Performance of growing-finishing pigs (25-112kg) fed a liquid diet with or without liquid co-products (Scholten et al. 1997).

	Control diet (meal + water)	Co-product diet	SE_M
Daily gain ($g\ day^{-1}$)	740^a	768^b	4.7
Feed intake ($kg\ day^{-1}$)	1.99^a	1.98^b	0.01
Feed conversion ratio	2.69^a	2.58^b	0.02
Lean meat percentage	55.3^c	54.8^d	0.16

Data in a row with a different superscript differ significantly (^{a,b} P<0.001; ^{c,d} P<0.05)

Table 5. Effect of inclusion level of wheat bottom stills (Greenwich Gold™) in the diet on the performance of growing-finisher pigs (2-90 kg) (Brooks et al. 2001).

	Greenwich Gold %†				
	0	15	22.5	30	SE_D
Daily gain (g)	779	759	746	793	15.9
Daily DM intake (g)	1608^a	1511	1523	1504^a	33.0
DM FCR	2.08^a	2.00	2.05^b	1.91^{ab}	0.041
Carcass weight (kg)	63.57	61.83	62.22	62.42	0.97
Backfat P2 (mm)	11.00	10.73	11.20	10.16	0.68
Killing-out %	70.38	70.85	71.70	69.70	0.93

^{a,b} Means with the same superscript differ at P<0.05 or greater

†Greenwich Gold contained ($g\ kg^{-1}$ fresh material) DM 192; crude protein 6.25; NDF 1.6; ash 1.28 and DE 3.3 $MJ\ kg^{-1}$. The diets were formulated to provide (at a nominal 87% DM) 13.4 MJ DE kg^{-1} and 12 and 9.5 g lysine kg^{-1} in the grower and finisher diets respectively.

The use of liquid food industry products can help solve an environmental problem for the food industry. However, it is important that while solving an environmental problem for the human food industry the livestock industry does not transfer the problem to the farm. Some environmentalists have been concerned that liquid feeding may increase environmental loading. By their nature, liquid diets tend to increase effluent volume. Liquid diets may also increase water consumption. Many co-products have high mineral content and it is essential that pigs be allowed access to a separate supply of water in order that they can maintain their homeostatic balance (Brooks *et al.* 1990). This is a requirement of the UK Welfare Codes (DEFRA 2003) and should be mandatory whenever liquid diets are used. In addition to its need to maintain homeostasis, the pig appears to have a behavioural need for water separate from any that it consumes with its food. Producers should not see this as a disadvantage, for our studies have shown that in grow-finish pigs performance is improved if they consume more water with their feed, and as a result have greater total water intake (Table 6). Subsequently, Barber *et al.* (1991) demonstrated that increasing the water content of liquid diets fed to growing pigs increased dry matter digestibility (Table 7).

Table 6. Voluntary water use and performance of grow-finish pigs offered liquid diets at different water to meal ratios (Gill et al. 1987).

	Water to dry ingredients ratio			
	2:1	2.5:1	3:1	3.5:1
Meal intake (kg d^{-1})	1.48	1.49	1.46	1.47
Voluntary water use (kg d^{-1})	1.26[a]	0.78[b]	0.44[c]	0.24[d]
Total water use (kg d^{-1})	4.23[a]	4.51[b]	4.86[c]	5.60[d]
Daily gain (kg d^{-1})	0.73[a]	0.74[a]	0.75[a, b]	0.77[b]
Dry Matter Feed Conversion Ratio	2.01	2.00	1.95	1.90
Water to feed ration (w/w)	2.97	3.12	3.36	3.68

[a, b, c] Means with the same superscript do not differ significantly at $P < 0.05$.

Table 7. Effect of water to feed ratio on diet digestibility (Barber et al. 1991).

	Water to dry ingredient ratio			
	2:1	2.67:1	3.33:1	4:1
Dry matter digestibility (%)	79.1[a]	77.8[a]	80.3[a, b]	82.9[b]
Estimated DE (MJ kg^{-1} DM)	15.1	15.0	15.4	15.8

[a, b] Means with the same superscript do not differ significantly at $P < 0.05$.

If this finding is taken together with the improved FCR found when pigs are fed liquid diets (see data reviewed by Jensen and Mikkelsen (1998) summarised in Table 1) we can conclude that pigs are able to extract more nutrients from liquid diets than from dry ones. It follows that the use of liquid diets, with or without co-products, may at the same time increase effluent volume and reduce nutrient load per litre. Therefore, it is very important when making comparisons of environmental loading produced by different feeding systems that these are expressed in terms of nutrients voided per kg growth made by the pig, or better still nutrients voided per kg meat produced.

Scholten *et al.* (1997) considered the outputs of pigs fed diets based on meal and water, or on co-products. They found that ammonia emissions were similar for pigs fed conventional liquid diets and those fed diets that included co-products (Table 8); and that manure production of pigs fed co-products was 2.4% higher when based on manure produced per kg growth. However, they did not measure the nutrient content of the manure. In studies with young pigs (7-25 kg), it was found that effluent volume increased when pigs were fed on liquid diets rather than dry pelleted diets (Table 9).

Table 8. Environmental impact of growing-finishing pigs fed a liquid diet with or without liquid co-products (Scholten et al. 1997).

	Control diet (meal + water)	Co-product diet
Ammonia emission (kg place^{-1} year^{-1})	1.9	2.0
Manure production (l place^{-1} year^{-1})	1,092	1,156
Manure production (l kg growth^{-1})	4.1	4.2
Dry matter content of the manure (%)	8.3	6.8
pH of the manure	7.3	7.5

Table 9. Production of effluent by weaner pigs fed dry and liquid diets (Russell et al. 1996).

	Trial 1			Trial 2		
	Dry	Liquid	SE_D	Dry	Liquid	SE_D
Daily gain (g d^{-1})	343	428	21***	397	454	14***
Total water use (ml pig^{-1} d^{-1})	1306	2298	64***	1499	2028	84**
Effluent production (ml pig^{-1} d^{-1})	754	1058	46**	982	1189	31*
Effluent production (l kg gain)[a]	2.20	2.47	+12.3%	2.47	2.62	+6.1%

[a] Note that in Trial 2 trough design for the liquid fed pigs was improved and resulted in a considerable reduction in effluent production per kg gain.

Some of the co-products that are used in liquid form could be dried and incorporated into conventional dry compounded feed. However, feeding them in liquid form removes the cost of drying and reduces dependence on non-renewable energy sources. On the debit side, the use of liquid co-products increases transportation costs, as more water is shipped with the dry matter. Consequently, there is an increased demand for non-renewable energy for transportation. As a result, disposing of some products by processing them through a pig may only be efficient if pig production units are situated close to the source of supply. However, in Europe many products are transported considerable distances as ‘back loads’ in tankers that would otherwise travel empty. Thus in real terms, there is only a marginal increase in fuel cost to set against the material (i.e. the difference between running the tanker empty and full).

Drying and subsequent incorporation into dry diets would not be a viable economic option for co-products with very low dry matter content. These materials would still have to be disposed of in an environmentally acceptable manner. The alternative routes for disposal of these materials would be through a sewerage system (either public or privately owned), land application or through addition to landfill sites. In developed economies both the economic and the environmental cost of such disposal continues to increase.

Therefore, when deciding whether to utilize co-products as feed stocks or make them environmentally non-damaging through waste treatment it is important to audit the alternative systems in their entirety to ensure that they are ultimately beneficial to the environment.

HEALTH BENEFITS OF LIQUID FEEDING SYSTEMS

There is considerable concern about the incidence of zoonoses in animal feeds and in particular the transmission of *Salmonella* through the food chain. In Europe, the animal feed industry has reduced the incidence of *Salmonella* in feed by stringent quality control and the use of high temperature treatments to kill any residual *Salmonella* in raw materials. Despite this, there is growing evidence that this approach has been unsuccessful in reducing the incidence of *Salmonella* in pigs on production units. Two hypotheses can be advanced to explain this. First, changes to the non-starch polysaccharide fraction of the diet resulting from heat treatment may produce a gastrointestinal environment that is more favourable to the colonisation of *Salmonella*. Secondly, non-pathogenic *Salmonella* may exclude pathogenic strains. Elimination of non-pathogenic *Salmonella* from feed may create ecological niches that are subsequently colonised by pathogenic strains.

A study of *Salmonella* incidence on German farms (von Altrock *et al.* 2000) identified the use of pelleted feed as a common risk factor for *Salmonella*. Bush (cited by United States Animal Health Association 1999) found that operations feeding a pelleted finisher diet had a 26 times greater risk of being *Salmonella* positive than those that fed a meal diet. They suggested that pelleted diets either influenced the gut environment such that pigs are more susceptible to *Salmonella* or, that pigs shed *Salmonella* that were already present. The same review (United States Animal Health Association 1999) also cited a study by Wong *et al.* who looked at the herd-level risk factors for the introduction and spread of *Salmonella* in Danish, German, Greek, Swedish and Dutch pig herds. They found that the incidence of *Salmonella* was 8.2% in herds feeding pelleted dry feed, 4.2% in herds feeding non-pelleted and dry feed but only 1% in herds feeding non-pelleted and wet feed. They also observed that the odds of a herd using whey being seropositive was 1% compared with 5.6% in herds not using whey. Danish studies have also shown a reduction in *Salmonella* when pigs are fed meal rather than pellets and fewer *Salmonella* positive pigs when using coarse ground rather than finely ground meal. (Jørgensen *et al.* 1999; Sloth *et al.* 1998).

It is clear from surveillance data that liquid feeding has a positive effect on gut health and reduces the incidence of *Salmonella*. In a survey of 320 farms in Holland, the incidence of sub-clinical *Salmonella* infection was found to be ten times lower on farms with liquid feeding than on farms feeding dry compound diets. The incidence was particularly low on farms that fed acidified cheese whey (Tielen *et al.* 1997). A more recent study (van der Wolf *et al.* 1999), found that automated liquid feeding of food industry co-products was associated with a decreased risk of infection.

It is important to note that most of the studies in which reductions in *Salmonella* incidence have been associated with liquid feeding have come from Denmark and The Netherlands. In both these countries, there is a tradition of using food industry co-products. As Scholten *et al*. (1999) have pointed out, the majority of these products have been fermented by lactic acid bacteria and as a result have a low pH and contain significant quantities of lactic acid. This high lactic acid concentration inhibits *Salmonella* in the feed and hence eliminates it at the start of the food chain. Consequently, the inclusion of fermented co-products in liquid diets for pigs makes a significant contribution to food safety. This has led workers in Europe to look more closely at the microbiology of liquid feed and to develop controlled fermentation of feed.

MICROBIAL ACTIVITY IN LIQUID FEED

Liquid feeding alters both the physico-chemical properties of the diet and its microbiology. Both of these factors are important in terms of pig health and performance. As noted above, there are benefits from including fermented co-products, with high levels of lactic acid, in diets for pigs. However, not all producers have access to liquid co-products. Nevertheless, a similar benefit can be obtained even when traditional dry diets are fed in liquid form. Twenty-five years ago, Smith (1976) showed that *Lactobacillus* species, which occur naturally on cereal grains, proliferate in a wet feed and reduce the pH. In his study, adding water to the meal at feeding time produced a pH of 5.8. Soaking the mixture for 24 h resulted in a massive proliferation of *Lactobacilli*, which produced lactic acid and reduced the pH to 4.1.

Virtually any combination of feed ingredients will ferment if left to steep in water. Almost all raw materials have a natural flora (mainly lactic acid bacteria and yeasts). Many may also have an undesirable microflora (coliforms, salmonellas and moulds). Generally, the dominant microflora that develops in liquid feed is the lactic acid bacteria (LAB). However, at low operating temperatures and particularly with some feed ingredients (e.g. by-products from brewing and ethanol production), yeasts will dominate. LAB fermentation is beneficial as it produces organic acids, primarily lactic acid. When incorporated into dry diets, lactic acid has a beneficial effect on feed intake, daily gain and FCR of piglets (Table 10). It seems likely that it is also having similar effects in liquid feeding systems. Importantly, recent research indicates that lactic acid is utilised as well as cornstarch (Everts *et al.* 2000), so the lactic acid makes a valuable contribution to the pig's energy supply.

Table 10. Effect of lactic acid percentage in diets on the performance of pigs (% increase over negative control) (Roth et al. 1993).

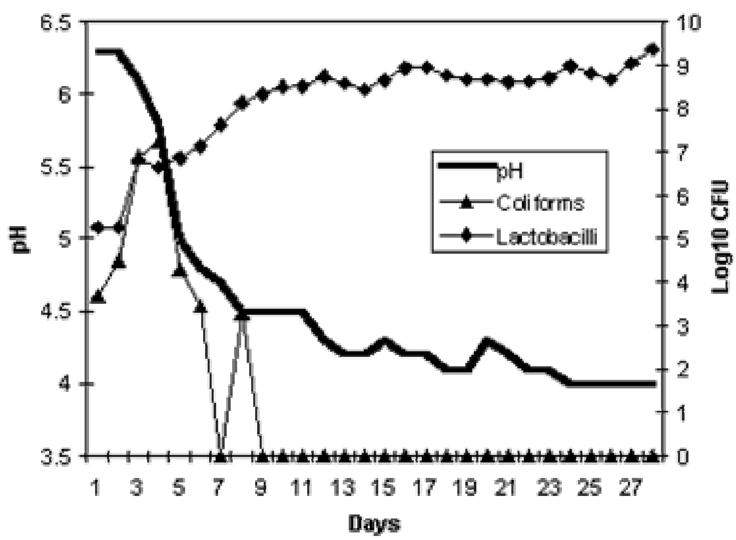
Lactic acid %	Daily gain	Feed Intake	FCR
0.8	+4.7	+6.1	+1.2
1.6	+8.1	+6.1	-1.8
2.4	+7.3	+5.4	-1.8

Yeast fermentation is not desirable. Starch is turned into alcohol and carbon dioxide. The alcohol can become too prevalent and the carbon dioxide indicates a significant loss of energy value. More importantly, just as in beer and wine making, fermentation by inappropriate yeasts can produce taints, which render the food unpalatable.

Because pipeline wet feeding systems are not sterilised between feeds it is inevitable that they are microbiologically active. Hansen and Mortenson (1989) conducted a large survey in Denmark and found that it took 3-5 days for the lactobacillus levels to elevate and stabilise in pipeline feeding systems. In their studies, they found that it was detrimental to sterilise pipeline-feeding systems as this removed the lactobacilli and increased the feed pH by 1.5-2.0 units. This in turn allowed coliform bacteria to proliferate for 1-5 days until the lactobacilli re-established themselves and lowered the pH. They found that sterilisation of pipeline feeding systems was actually disadvantageous, as outbreaks of diarrhoea often resulted from the coliform ‘bloom’ which followed the sterilisation of pipeline systems.

Studies at the University of Plymouth (Geary 1997; Geary *et al.* 1999; Geary *et al.* 1996; Russell *et al.* 1996) have shown that a lactobacillus population develops in *ad libitum* liquid feeding systems for weaner pigs and that this is accompanied by a reduction of pH and *E. Coli* population (Figure 1).

Figure 1. Change in pH and microbial population of liquid feed over time (Geary et al. 1999).



Jensen *et al*. (1998) have reviewed the effects on performance of presenting weaner pigs with dry, freshly prepared liquid, or fermented liquid feed (Table 11). Compared with feeding dry diets weight gain was improved by an average of 12.3% when feed was presented in liquid form and by a further 13.4% if the liquid feed was fermented. However, FCR was generally worse on liquid feed (LF) and FLF than on dry feed. This is in contrast to the results obtained with finishing pigs (Table 1) and probably reflects differences in feeding behaviour between older and newly weaned pigs.

Table 11. Improvement (%) in growth rate and food conversion ratio in experiments in which the performance of pigs fed dry feeding (DF), liquid feed (LF) or fermented liquid feed (FLF) was compared (After Jensen et al. 1998).

		Improved daily weight gain		Improved food conversion ratio	
	Number of trials	Mean ± SD	Range	Mean ± SD	Range
LF v. DF	10	12.3 ± 9.4	-7.5 - 34.2	-4.1 ± 11.8	-32.6 - 10.1
FLF v. DF	4	22.3 ± 13.2	9.2 - 43.8	-10.9 ± 19.7	-44.3 - 5.8
FLF v. LF	3	13.4 ± 7.1	5.7 - 22.9	-1.4 ± 2.4	-4.8 - 0.6

FERMENTATION REDUCES THE INCIDENCE OF ENTEROPATHOGENS IN LIQUID FEED

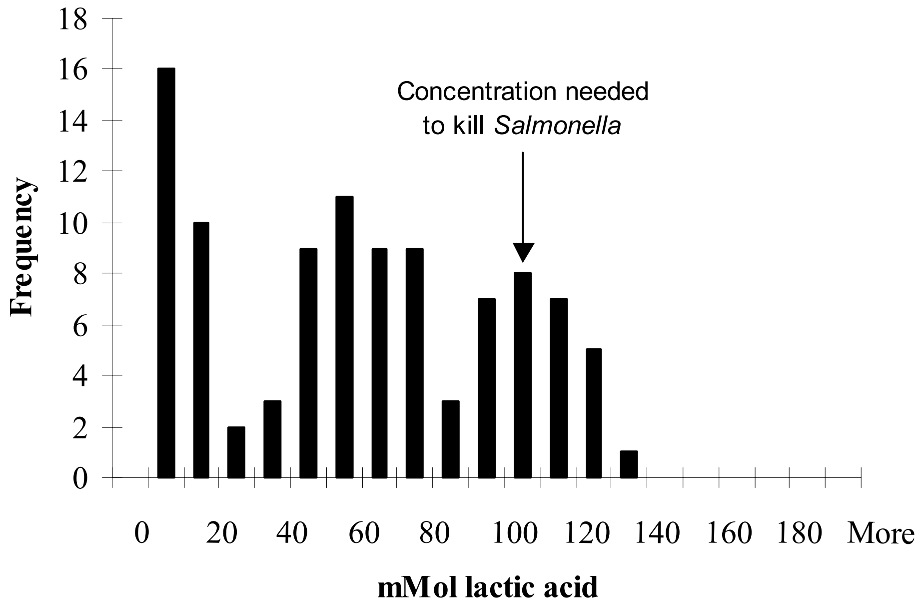
As noted earlier, the animal feed industry makes strenuous efforts to reduce the incidence of enteropathogens (particularly *Salmonella* spp.) from dry diets. However, no matter how effective this process is, there remains the possibility that the feed can become re-contaminated between leaving the mill and being eaten by the pig. An advantage of properly fermented liquid feed is that the acid content of the feed significantly reduces the risk of re-contamination.

A lactic acid concentration in feed of 70 mMol was found to be bacteriostatic to *Salmonella*, but higher levels (>100 mMol) are needed in order to be bactericidal (Beal, Niven and Brooks unpublished data). Unfortunately, natural fermentations cannot be relied upon to produce these concentrations of acid. For example, in samples of wheat from across the UK, fermented for 24h at 30°C, the lactic acid level varied from 0 to 50 (8.7±12.2) mMol. After 72h the range was from 0.14 to 135 (48±38) mMol lactic acid (Figure 2).

Only circa 10% of natural fermentations achieved the threshold level of 100 mMol lactic acid needed to eliminate *Salmonella.*

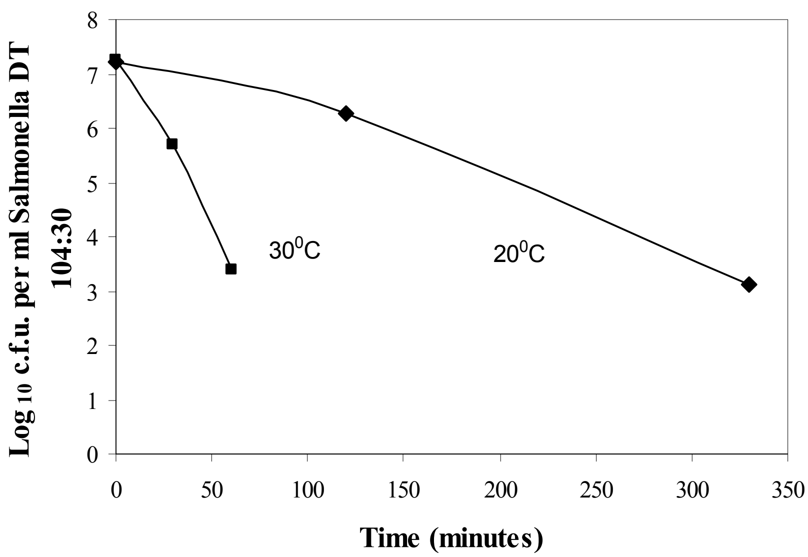
This problem can be overcome by inoculating liquid feed with LAB that produce lactic acid rapidly, and to a high concentration. We have identified a number of LAB species that are capable of producing in excess of 100 mMol lactic acid with less than 30 mMol acetic acid in 24 h. However, in the EU only microorganisms that have been registered as zootechnical additives can be used as inoculants. This is extremely restrictive and most organisms that have been registered are probiotics, that have been developed for other purposes, and may not have particularly good lactic acid producing properties. The reason that the EU requires registration of LAB is concern about the possible transfer of antibiotic resistant genes. In a number of other countries around the world LAB have 'Generally Recognised as Safe' (GRAS) status, so a wider range of organisms could be used as inoculants.

Figure 2. Lactic acid produced by the natural fermentation of wheat at 30°C for 72h (Beal, Niven and Brooks unpublished data).



In studies at Plymouth, *Salmonella typhimurium* was rapidly excluded when it was introduced into feed that has been fermented for 48, 72 or 96 h with *Pediococcus pentosaceus* (Beal *et al.* 2002). However, the death rate of *Salmonella typhimurium* is very temperature dependent and was much faster at 30°C than at 20°C (Figure 3).

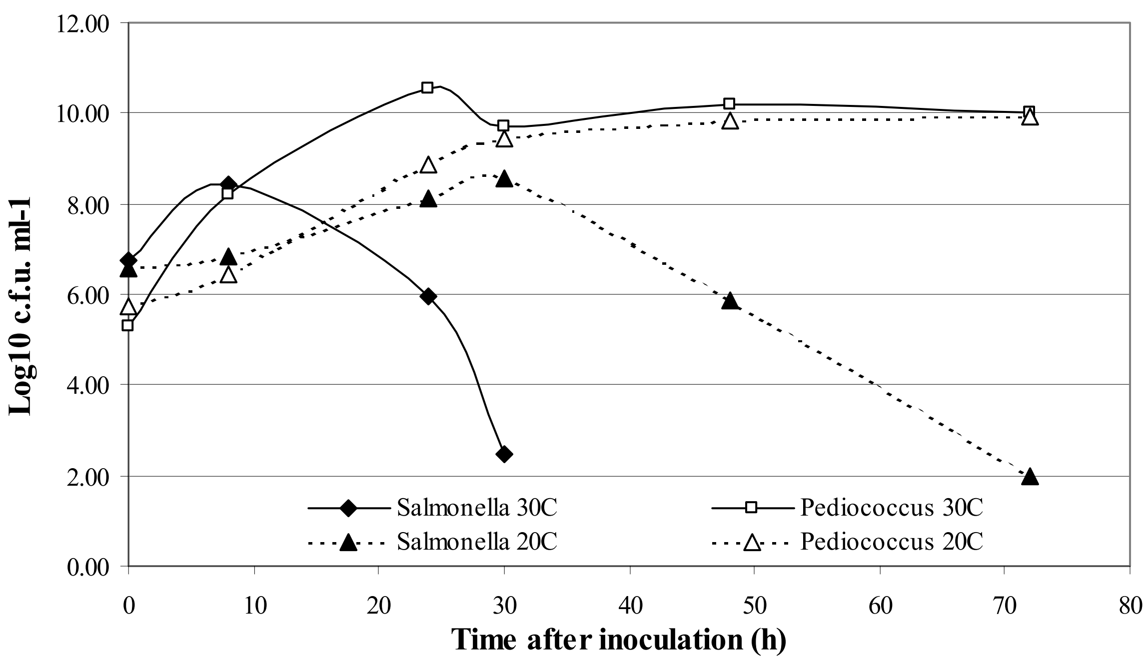
Figure 3. Disappearance of Salmonella after inoculation into fermented feed maintained at 20°C or 30° C (Beal et al. 2002).



In another study (van Winsen *et al.* 1997), it was found that pig feed fermented with *Lact. plantarum* had a bacteriostatic effect on *Salmonella* during the first two hours following inoculation and a bactericidal effect thereafter. Six hours after inoculation *Salmonella typhimurium* could not be detected in the FLF. In contrast, *Salmonella typhimurium* added to non-fermented feed survived and multiplied (van Winsen *et al.* 1997). More recently, it was been shown that it is the lactic acid concentration of the fermented feed that is responsible for this effect (van Winsen *et al.* 2000).

Studies in our laboratory have shown that when *Salmonella typhimurium* DT104:30 and *Pediococcus pentosaceus* were co-inoculated into liquid feed, the *Pediococcus pentosaceus* rapidly dominated the fermentation and reduced *Salmonella typhimurium* to undetectable levels (Beal *et al.* 2002). However, this effect was also temperature dependent (Figure 4). The decimal reduction time (D_{value}) was significantly better at 30° C (D_{value} 34 – 45 min) than at 20^{o} C (D_{value} 137 – 250 min).

Figure 4. Disappearance of Salmonella after co-inoculation with Pediococcus pentacaceus at 20°C or 30° C (Beal et al. 2002).



FLF has also been shown to be effective in reducing the incidence of pathogenic *E.coli* (Beal *et al.* 2001) (Table 12). However, LAB species differ markedly in their effects on the survival of enterotoxigenic *E. coli* (Hillman *et al.* 1994a; Hillman *et al.* 1994b; Hillman *et al.* 1995).

Jensen and Mikkelsen (1998) demonstrated the importance of temperature in controlling fermentation and lowering the pH of the feed. They used a 0.5 residue, and eight-hourly replenishment of the tank. They found that pH reached a steady state in 50 h when the tank was maintained at 25°C, but that it took around 100 h when the tank was maintained at 15°C.

We now favour even higher operating temperatures (circa 30° C). At this temperature, and using the right inoculant it is possible to achieve the desired lactic acid concentration (i.e. >100 mMol) in 24h.

Table 12. Decimal reduction time (min) of selected micro-organisms added to FLF that had been fermented with Lact. plantarum for 24 h, 48 h, 72 h and 96 h (Beal et al. 2001).

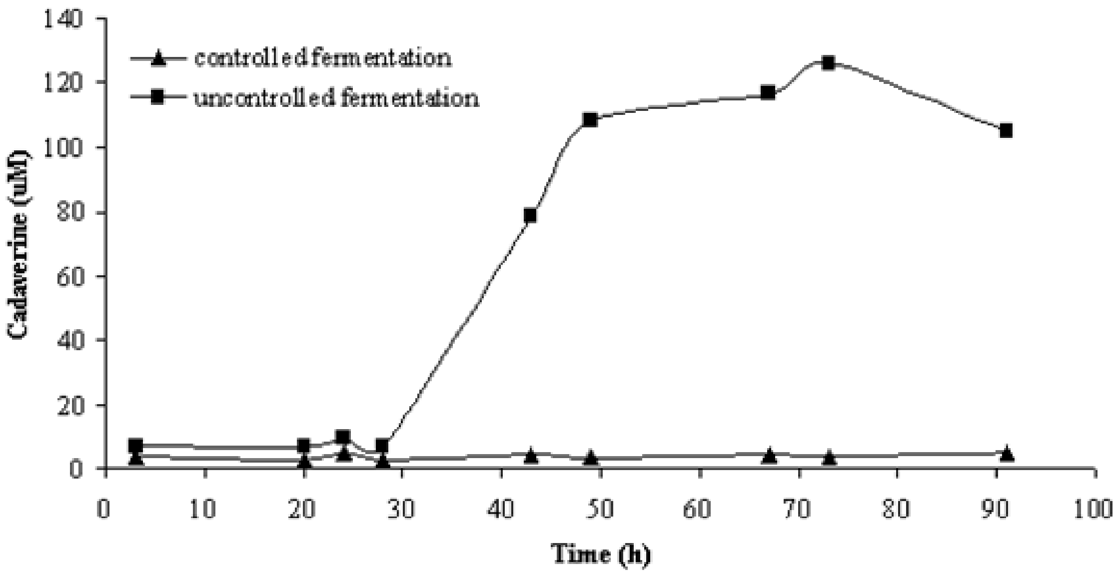
	Decimal reduction time (min)			
Serotype	24 h	48 h	72 h	96 h
E.coli K88 (99)	nt	25.2[a]	23.7[a]	22.9[a]
E.coli K88 (100)	nt	26.1[a]	23.6[ab]	17.4[b]
E.coli K88 (101)	nt	22.3[a]	24.2[a]	24.3[a]
E.coli K99 (185)	nt	22.0[a]	16.5[b]	15.8[b]
E.coli K99 (230)	nt	22.2[a]	14.6[b]	14.0[b]
E.coli 0157:H7	nt	12.2[a]	9.3[b]	10.3[b]
Salm. typhimurium DT104B (342A)	46.5[a]	31.6[b]	13.8[c]	nt
Salm. typhimurium DT104B (342B)	35.3[a]	20.9[b]	nt	nt
Salm. typhimurium DT193 (20)	32.0[a]	15.7[b]	nt	nt
Salm. derby (16)	38.2[a]	25.3[b]	nt	nt
Salm. goldcoast (245)	38.8[a]	15.6[b]	nt	nt
Salm. anatum (41A)	26.4[a]	14.4[b]	11.9[c]	nt

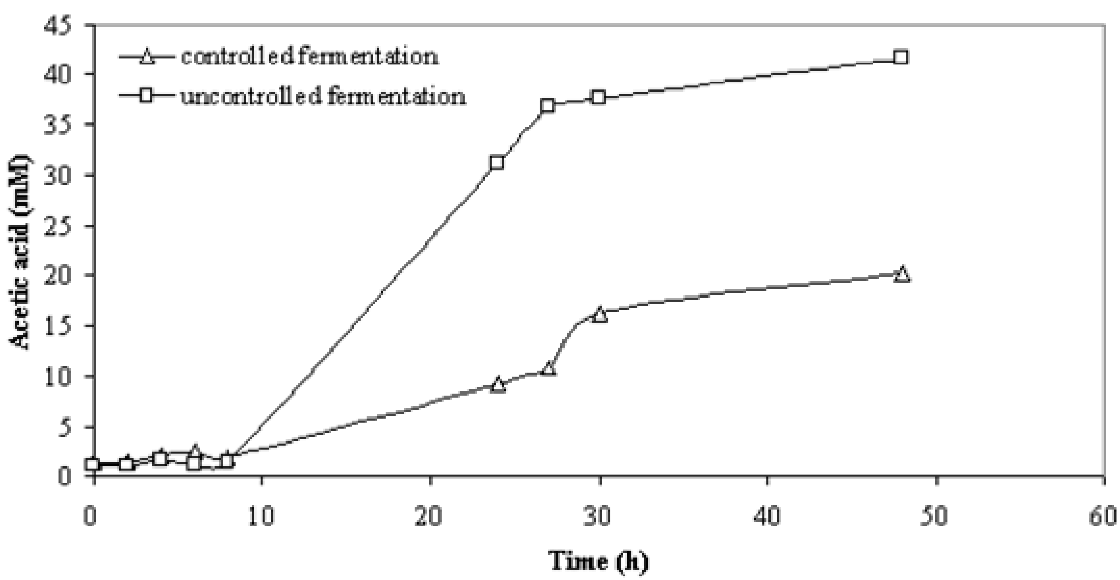
[a, b, c] Means in the same row with the same superscript do not differ at $P < 0.05$

Palatability is also an important issue, particularly when feeding FLF to young pigs. Our studies have shown that pigs are tolerant of dietary lactic acid concentrations up to 200 mMol, but low levels of other short chain fatty acids like acetic acid can adversely affect intake. The presence of biogenic amines in the diet may also have adverse effects on intake. The data in Figure 5 shows the comparative development of acetic acid and a biogenic amine (cadaverine) in fermented feed produced by either a controlled fermentation (feed inoculated with a selected LAB) or an uncontrolled fermentation (fermented by the native flora). This data reinforces the importance of using selected LAB inoculants to control fermentation and helps explain some of the palatability problems that we have observed on commercial pig units.

Our initial studies of FLF used continuous fermentation. However, this created many problems on commercial units. Producers were unable to deal with the complexity of the system or with the number of diets that had to be prepared. Therefore, current work is centring on the use of batch fermentation. This is more easily controlled and if problems occur, such as the development of a mal-fermentation, they can be recovered from more easily. Much current work in Europe is based on fermentation of just the carbohydrate fraction of the diet. This creates a product that can then be incorporated into a range of different diets. In addition, the fermentation process is simpler, more predictable and more reliable.

Figure 5. **Development of acetic acid and cadaverine in controlled and uncontrolled fermentations of liquid feed (Niven, Beal and Brooks unpublished data).**





BENEFICIAL EFFECTS OF FERMENTED LIQUID FEED

As noted earlier fermented liquid feed may reduce the incidence of Salmonella in slaughter pigs. In addition, there is growing evidence that FLF may confer specific benefits to newly weaned pigs. FLF may benefit the weaner pig by:

- Improving feed intake. Well fermented feed may maintain the growth of the gut epithelium
- Providing an acid diet. This may help control pathogens both in the feed and in the pig's gut. It also helps with protein digestion.
- Supplying lactic acid bacteria. The presence of large populations of LAB in the diet may have a beneficial effect on the lower gut microflora.

The fastest growing tissue in the pig's body is the epithelial lining of the small intestine. Many of the nutrients needed for growth are directly absorbed from the gut lumen. Even transient starvation will result in a rapid reduction in villus height and thus reduce the absorptive capacity of the gut (Pluske *et al.* 1996a; Pluske *et al.* 1996b). Conversely, a diet that is palatable and well accepted by the newly weaned pig will ensure an adequate supply of nutrients to the brush border.

The weaned pig has an insufficiency of stomach acid, which is the first line of defence against bacterial invasion (Cranwell *et al.* 1976; Smith *et al.* 1963). Manipulation of stomach acidity, through lactic acid supplementation of the diet (Thomlinson *et al.* 1981) feeding fermented milk (Dunshea *et al.* 2000; Ratcliffe *et al.* 1985; Ratcliffe *et al.* 1986) or through lactic supplementation of water (Cole *et al.* 1968) all reduced gastric pH and the number of coliforms in the stomach. Similarly, Mikkelson and Jensen (1997) found that fermented liquid feed results in a significant increase in lactic acid content in the stomach and some small but significant changes in other sections of the gut.

Recent studies have shown that feed form can have an effect on the pH of the GIT (Table 13) with the lowest pH being found in pigs that continued to suckle their dams (Moran 2001).

Table 13. Effect of dietary treatment on the pH of the intestinal contents of piglets 14 days post-weaning (Moran 2001).

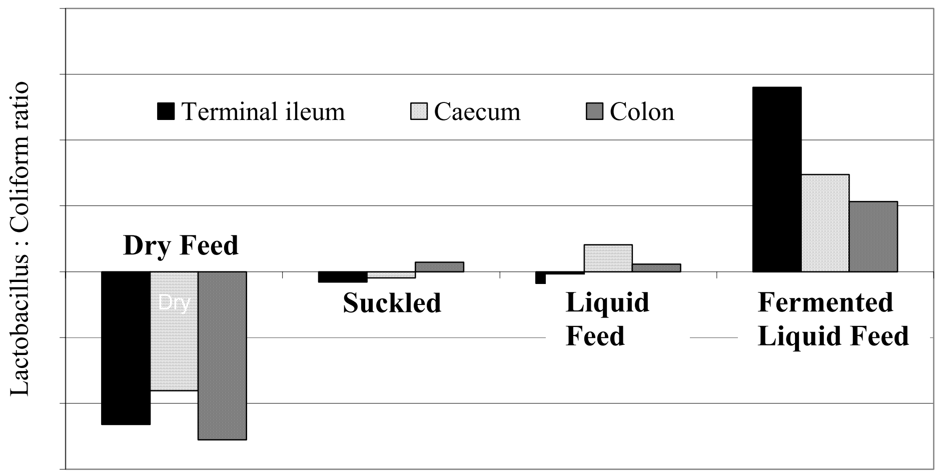
	Dietary treatment			
	Suckled	Dry pelleted feed	Liquid feed	FLF
Stomach	2.4^{b}	3.9^{ab}	4.8^{a}	3.9^{ab}
Terminal ileum	5.9^{bc}	6.3^{abc}	6.4^{abc}	6.1^{abc}
Caecum	6.1^{ab}	5.8^{b}	6.0^{ab}	6.0^{ab}
Colon	6.6^{a}	5.9^{b}	6.0^{ab}	6.2^{ab}

$^{a, b, c}$ Means in the same row with the same superscript do not differ at $P < 0.05$

Feeding fermented liquid feed does not appear to produce any significant effect on the number of lactic acid bacteria throughout the gut but it does dramatically reduce the number of coliforms in the lower small intestine, caecum and colon (Jensen *et al.* 1998; Moran 2001; Muralidhara *et al.*

1977; van Winsen *et al.* 2001). The ratio of lactic acid bacteria to coliforms in the lower gut of pigs weaned onto liquid diets was very similar to that of pigs that continued to suckle the sow (Moran 2001). However, when the pigs were weaned onto dry diets there was a significant shift in the ratio towards the coliform bacteria. Conversely, when they were weaned onto FLF the number of coliforms was reduced and the ratio shifted in favour of the lactic acid bacteria (Figure 6). This is similar to the response that occurs when some antibiotic growth promoters are fed (Jensen 1998), and suggests that FLF might have a valuable role as part of a strategy for the management of pigs in the absence of antibiotic growth promoters.

Figure 6. Ratio of Coliforms to Lactic Acid Bacteria in the gut of post-weaned pigs fed dry pellets, non-fermented liquid feed (NFLF) or fermented liquid feed (FLF) compared with pigs that continued to suckle their dam without creep feeding (Moran 2001).

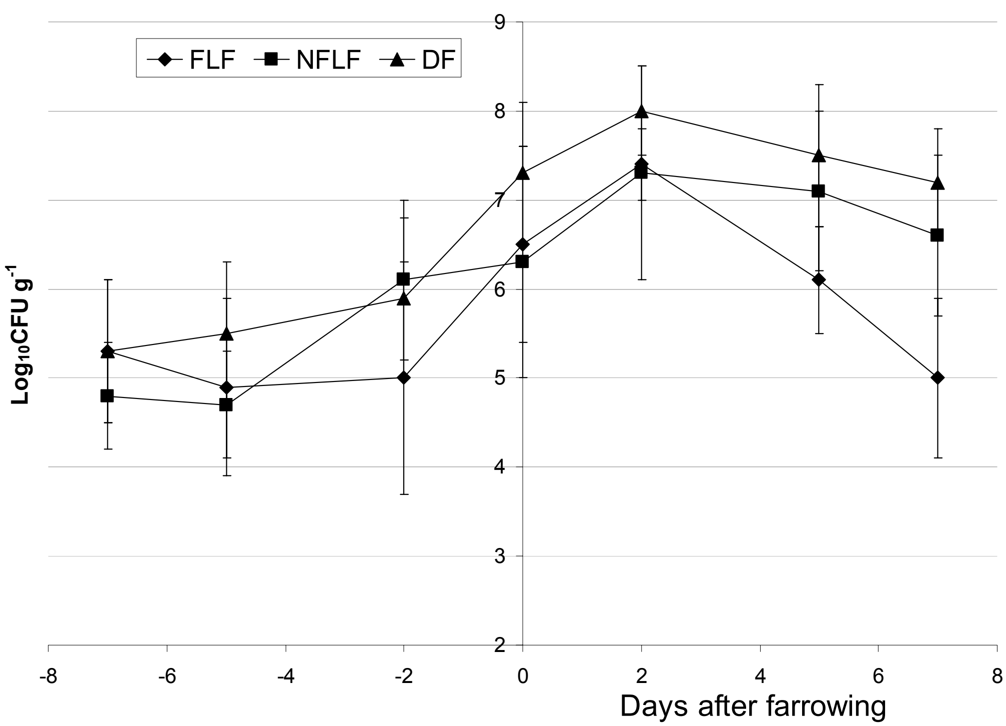


FEEDING LACTIC ACID BACTERIA TO THE SOW IS A WAY OF INFLUENCING GUT COLONISATION IN HER PIGLETS

At birth the pig usually has a sterile gut and acquires its characteristic flora during and following birth through contact with its mother and its surroundings. The most significant contributor of bacteria to the piglet's surroundings is the sow. Therefore, we reasoned that if the gut microflora of the sow could be manipulated this would impact on the development of the piglet's gut microflora. To this end sows were fed diets fermented with aggregating *Lab. salivarius* derived from healthy sows and were compared with sows fed dry diets or non-fermented liquid diets prepared immediately before feeding (Demečková *et al.* 2002). The treatments had no effect on the number of LAB in sows' faeces, but feeding FLF significantly reduced the number of coliforms shed (Figure 7). The faeces of piglets suckled by sows fed FLF contained significantly more lactic acid bacteria (7.7 vs.7.3 $\log_{10}$ CFU g^{-1}) and significantly less coliforms (7.5 vs. 8.1 $\log_{10}$ CFU g^{-1}) than the faeces of piglets suckling sows fed dry feed.

The quality of the sow's colostrum was also affected by diet. Colostrum from sows fed FLF had significantly greater mitogenic activity on both intestinal cells and blood lymphocytes compared with colostrum from sows fed a dry diet. It can be anticipated that an increase in the proliferation of intestinal epithelium will result in an overall increase in the epithelial cell population and a corresponding increase in villus height. Thus, colostrum with a higher mitogenic activity has the potential to both accelerate the maturation of the newborn's GI tract and provide the piglet with better protection by maintaining the integrity of the intestinal mucosa. The observed increase in the mitogenic activity of lymphocytes is very important. It is clear that the immunostimulatory effects depend on both the organism used and the dose (Donnet-Hughes *et al.* 1999; Gill *et al.* 2001), and generally requires continued ingestion of LAB. Dose levels required to produce an immunostimulatory effect appear to be of the order 10^9 CFU. This level is consistent with the daily dose of LAB provided by FLF.

Figure 7. Faecal counts of coliforms and LAB in the sows fed different diet for the period of 1 week before farrowing till 1 week after parturition (Demečková et al. 2002).



CONCLUSIONS

In some counties, the adoption of liquid feeding, has significantly reduced the incidence of *Salmonella*, particularly when it is allied to the use of acidic food industry co-products or fermented feed. Fermentation, is one of the oldest, safest and most natural methods of feed preservation and it is pleasing to see that it is being rediscovered and put to good use in the pig industry. The use of acidic components and the controlled fermentation of liquid feed provide a simple mechanism whereby the bio-safety of feed can be increased. The ability of fermented feed to exclude pathogens such as *Salmonella* can make an important contribution to food safety. This capability will increase in importance as legislators press the pig industry to remove antibiotic growth promoters from their diets. However, legislators will also need to be sympathetic to the needs of the industry and ensure that legislation governing the use of LAB inoculants ensures food safety but does not become a deterrent to the development of this exciting and beneficial technology.

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HOW WE PRODUCE A UNIFORM HIGH QUALITY MARKET PIG

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INTRODUCTION

For the past thirty years the pig industry has enjoyed the luxury of a single clear message from its end-user: reduce backfat. With the grading grid as the incentive, and by a combination of genetics and nutrition, this reduction has been spectacularly successful. Lean growth rate has improved some 60% over 30 years, the accumulated improvement worth some $400 million per year in Canada. Since a kilo of lean requires over three times less energy than a kilo of fat, producers also benefited from large reductions in feed costs.

With fatness now under control the situation is changing. Meat runs the risk of falling seriously behind everything else on the supermarket shelf in quality, uniformity and above all *predictability*. The notion of quality stretches far beyond the product into responsibility for animal welfare and food safety. The industry's present dilemma arises from five factors:

- Uncertain market conditions with cyclical profitability.
- Poor communication of what constitutes good quality.
- Payment systems that no longer reflect what the market requires.
- Independent management of the different steps in the pork value chain.
- Possible effects of animal health on quality and uniformity.

This paper looks at the main components of quality, and asks how the industry must change to ensure its future competitive position.

PRODUCT REQUIREMENTS

What is Quality?

Product quality includes all the factors that describe whether the product meets the customer's expectation. This includes not only the composition of the meat and its eating and processing properties but also the size and shape of the joint (see Table 1). Thus, the weight and length of a loin is as important as the fat content and eating properties.

Uniformity

Achieving a uniform and predictable product is perhaps the greatest challenge, given the inherent biological variation of meat. As well as ensuring that a higher proportion of product meets the customer's expectation, the unpredictable nature of meat is one of its most potentially damaging properties.

Table 1. Some components of meat quality.

Fat:lean ratio
Muscle distribution
Individual joint weight, size and shape
Intramuscular fat (marbling)
Intermuscular fat
Waterholding capacity
Rate of pH (acidity) change
Muscle and fat colour
Muscle and fat firmness
Ease of slicing
PSE and DFD
Tenderness, juiciness, and flavour
Curing loss
Bacteriology

Traceability

Today the responsibility of the pig industry goes well beyond the physical form of the product. There is public accountability for food safety. As medical knowledge grows, there will be increasing responsibility for human dietary health. There will also be responsibility to defend the various claims that add value to the finished product, involving for example "high welfare, organic, barley-fed, omega-3, animal protein-free or antibiotic-free". The need for traceability arises from the following:

- Rising attention to food safety.
- Need for zoning in the event of epidemic animal disease (eg foot and mouth).
- Tracking the source of drug residues.
- Recall in the event of contamination (eg pesticides).
- Feedback to allow quality control.
- Protection against bioterrorism.
- Marketing the 'Canada Brand' worldwide.

Traceability as a key *point of difference* will be a major competitive advantage for Canada, as the country's cost advantages are eroded by US and EU subsidies.

HITTING THE MARK ON MEAT QUALITY

Breeds and Genetic Selection

The genetic options to improve quality are choice of breeds and lines, selection within breeds, and the use of individual genes. Since eating quality traits have low heritabilities and are difficult to measure in the live animal, most of the selection effort within lines has been directed to more rewarding growth and fat traits. Sib selection, which is the use of measurements on slaughtered littermates to predict genetic merit of candidate breeding herd replacements, is slow and expensive.

For some fresh meat markets, the Duroc breed has an advantage in eating quality, at least partly resulting from greater intramuscular fat. The Berkshire is favoured for fatter Japan products but is uneconomic. In spite of its added fat, the Meishan does not have the same advantage as the Duroc, and the proportion of Meishan in slaughter generation products has so far been too low to improve quality. Extremely lean types appear more susceptible to poor handling that can lead, for example, to two-tone meat.

Individual Genes

The halothane gene was probably unique in farm livestock as the mutation actually responsible for the greatest source of PSE (pale soft exudative) meat. Thanks to the DNA test developed at Toronto and Guelph, the gene should now be largely eliminated from nucleus lines. Some residual testing will be needed to check that the mutation does not recur. Third Wave AgBio of Madison Wisconsin has developed a bulk halothane test that shows whether the gene is present in a single test on many pooled samples. This opens the door to cost-effective testing on the meat itself.

There is much interest in finding other genes that might be used to improve quality, but so far with only modest success. The new science of *functional genomics* is now building on gene maps to measure the level of expression of individual genes. It can show which genes are expressed in certain environmental conditions. For example, it will identify the genes that are expressed only when animals are stressed and lead to poor meat quality. The understanding of genetic pathways could therefore equally lead to husbandry rather than genetic solutions.

Nutrition

Through fatness and rate of growth, nutrition can clearly impact meat quality. Genetically lean pigs obtain a higher proportion of the fatty acids needed for tissue deposition from the diet. Hence their body fat contains a higher proportion of unsaturated vegetable fats, and may be softer. Fat firmness can be affected by changing the fatty acid content of the diet.

In future pig nutrition could offer a means to improve the healthiness of the meat to the consumer. Examples might be minerals and vitamins, choline as a brain neurotransmitter, CLA (conjugated linoleic acid) in cancer prevention, and cholesterol control agents.

Transport and Handling

Good treatment from farm to slaughter is critical for good quality. This includes loading, the truck environment, length of journey, unloading, mixing, resting time, temperature in holding pens, ventilation, the race to the point of stunning, stunning itself, and slaughter. Quiet handling at all stages is essential. Procedures through the plant need to be optimized and standardized. For example, one of the main variables affecting quality in the plant is the cooling rate.

IN SEARCH OF UNIFORMITY

Genetics

The ultimate solution to genetic uniformity might be cloning, which would produce individuals that are largely genetically identical. By cloning the best individuals from nucleus herds, clones could be genetically superior to the mean of the nucleus. However, the notion that this would give 'peas in a pod' uniformity is a myth. With a heritability of only 30%, some 70% of the variation in most eating quality traits is non-genetic and would remain after cloning. Additionally, non-surgical introduction of frozen embryos on commercial farms would be needed to deliver cloning, and these are not yet feasible in practice.

At present the best option to improve genetic uniformity would be to select terminal sires for AI (artificial insemination) into a very narrow band of predicted genetic merit. AI allows very few sires that can be very similar in genetic merit. The dam-line GP sires of parent females can similarly be selected into a narrow range.

Production and Health

Assuming a uniform feed and environment, one of the greatest causes of variation will be differences in feed intake. Common causes of a reduction in intake are poor pig health, overstocking, and high ambient temperatures.

With females 10% leaner than barrows, one of the greatest sources of product variation is the sex difference. Split sex feeding ensures the nutrient requirements of both sexes are met, but it does not remove the difference in performance. The solution would be to produce only one sex. Semen sexing by staining sperm and then physical sorting by laser (flow cytometry) is possible but prohibitively slow, with little prospect of speeding up. The hope is to devise sex specific antibodies that could destroy the unwanted gender of sperm by simple addition to the ejaculate at the point of collection.

Reward System

One of the fundamental causes of poor uniformity has been that the payment system for carcases has not reflected what the processor really wants. For example, a grading grid that simply rewards low backfat gives no information or incentive to control other aspects of carcass and meat quality. Thus, there may be a large range in ham shapes and joint distribution at the same fatness. Some genotypes for example containing the halothane gene may be lean at the expense of muscle quality that may tend towards PSE.

Uniformity is not a realistic goal until the requirements of the market are translated into clear parameters for quality that the producer can use as targets. This requires an understanding of the needs of the customer and how to measure real value. The industry must question whether weight and fatness are a sufficient description of value in 2003.

Vertical Coordination

Much of the loss in uniformity and value to the pig industry has arisen from poor communication among the steps in the pork value chain. Sharing information and working together can increase the recovery of value by 20-30%. As an example, changing the feed to improve meat quality would add cost for the producer, but would increase profit for the processor. In many cases at present this added value would be taken by the processor at the expense of the producer. In a vertically coordinated system such as Maple Leaf, the added value can be shared equally.

Vertical integration in the form of common ownership of multiple stages of the pork value chain is not essential. What is needed is coordinated action to maximize overall value. The opportunity then exists for differentiated products with added value. Production can also be partitioned to accommodate the requirements of different markets. Vertical coordination also gives a unique opportunity for high levels of traceability.

Six Sigma

At Maple Leaf vertical coordination has allowed the adoption of Six Sigma at all levels of the value chain. Pioneered by Motorola and GE, and widely used in the aviation industry, Six Sigma is a formal analytical approach to the control of unwanted variation in meeting customer requirements. It provides a disciplined framework for describing customer needs, analysis of the production process, and quality control by continuous measurement. It also provides for the design of experiments on the farm or in the plant to investigate unknown causes of variation.

TRACEABILITY

Methods of Tracking

The ultimate objective will be to track every piece of meat from plate to farm through each step in the production, slaughter, processing and distribution chain. Some of the possible methods might include ear tags, tattoos, bar codes, “smart” trays and gambrels, creation of specific antibodies, molecular bar codes, and quantum dots.

Live animal tracking from birth to slaughter is very possible using ear tags and tattoos. Tracking through the slaughter and processing plants at modern line speeds with so many different steps and routes will be extremely expensive. For a high-speed plant the capital cost could be $10-20 million with development costs of a further $4 million. Tracking the packaged product through distribution and retail will be much cheaper since codes can be printed on the wrapper. If necessary, consumer access could be provided through product codes and a website.

DNA Tracking from Meat to Farm

In an evolution of forensic genetic fingerprinting, DNA tracking can link meat back to the farm of origin, by-passing the expensive step of tracking through the plant. The attraction of DNA typing is that it requires no capital investment. DNA typing is very accurate, and relatively free of the human error from hand-labeling systems. It can therefore be used to audit and verify other tracking systems. It works on cooked as well as fresh material.

In December 2002, Maple Leaf placed a contract with Pyxis Genomics Inc. to identify a "DNA panel" that can track from meat back to the mother of the slaughter pig. The mother's identity indicates the farm and date of birth of the progeny. Live animal tracking then links to the nursery and finisher barns, the truck, and the slaughter plant. Since boars are used across farms by AI, tracking to the terminal sire would not identify the farm of origin.

How DNA Tracking Works

Tracking will use naturally occurring base changes in the DNA code known as single nucleotide polymorphisms or "snips" (SNPs). It is expected that 200 to 300 SNP's will be needed to discriminate between mothers that are full sisters on different farms. All replacement breeding females will be DNA typed at first farrowing and their genotype for the panel entered into a database. When meat is DNA typed, it can then be cross-matched to the mother using the database.

The cost of DNA typing is currently around $70 per female, or $1-2 per slaughter pig. Within three years, the cost of high speed SNP typing is expected to drop to around $6 per female, or 10 cents per slaughter pig. Large economies of scale are expected since the DNA results on the mother are not required until five months after the birth of her first litter. At first, tests on meat will have a turnaround of some 48 hours, but this will be greatly reduced as DNA testing becomes available in kits that can be used on-site.

The Maple Leaf DNA panel is expected to be ready in the autumn of 2003. During 2004, it will be introduced for the 93 000 sows in Maple Leaf's own Elite Swine, and for other producers supplying Maple Leaf plants.

ACTION POINTS FOR THE INDUSTRY

So what immediate action could the industry take today to ensure a uniform high quality product? Here are some suggestions.

- Understand customer requirements and set clear targets for performance.
- Introduce a clear payment system that measures quality and rewards value for meat that falls within the desired range.

- Vertically coordinate the steps in the value chain. Take action that will maximize aggregated profits from the whole value chain. Be prepared to communicate and share costs and rewards.

- Introduce traceability as a means of identifying the causes of poor quality. Be seen to be responsible and accountable to the consumer.

- Work to improve pig health as a major source of potential advance in quality and uniformity.

- Adopt uniform genotypes in terms of choice of lines, and selection of AI sires within lines.

- Operate split sex feeding to optimize nutrition for barrows and gilts.

- Standardize husbandry and stress-free handling practices, without overstocking and extremes of temperature.

Longer term, perhaps the greatest step forward would be production of a single sex of slaughter animal. Research on cost-effective methods of semen sexing should therefore be encouraged. Better methods are required to measure and reward quality on-line at the slaughter plant. For genetic selection at nucleus level, methods are also required to measure meat quality in the live breeding animal.

It is clear that a move to the next level of quality and uniformity is well within the grasp of the industry. This will be manifest to importers of pork products from Canada as higher quality, coupled with traceability that underwrites both food safety and value-added propositions. Public and private sector research should work together down the route that will give a competitive advantage in quality, safety and added value.

Can We Compete in the Global Marketplace?

NEW EMERGING COMPETITORS – WHY ARE THEY A CONCERN?

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ABSTRACT

Pork production continues to evolve to fewer and larger operations that use innovative methods to improve vertical coordination. Established large firms appear to have some cost advantage over traditional producers, but face new competition from expansion in "new" hog regions in Central and Western Canada and Brazil. These two Western Hemisphere countries are rapidly growing pork production and exports. The technologies that allowed emerging large scale operations to displace existing traditional pork producers are easily adopted in new areas that have low feed cost, fewer neighbors, and fewer regulations.

INTRODUCTION

The pork industry has changed dramatically in the last 10 years and it is hard to tell who is a "new" competitor and the answer varies depending on who is asking. Many producers view large highly coordinated companies as new competitors. Or, they view packers that produce hogs as their new competition. Some Iowa producers still view North Carolina as a new competitor even though they haven't added a sow since 1996. Many in the US would view Canada as a new kid on the block. Yet others look to Brazil as the next new pork powerhouse as it expands pork production, processing and grows exports from a region that is FMD free. And, finally, some producers look at other proteins, beef, poultry, plant sources, as the competition. This paper will briefly review several of these competitors and try to offer some insight to their competitiveness in the future.

GLOBAL PORK PRODUCTION AND TRADE

Let's first look at global pork production and pork trade to determine who the players are and how they have changed in recent years. China remains the world leader in pork production (Table 1) with approximately half of the estimated world production. China is still expanding production at a double digit pace, although slower than its growth a decade ago. The next largest producer is the 15-country block of the EU where 21 percent of world production occurs. However, growth in the EU has dropped to 2 percent from 1998-2002 due in part to environmental and animal disease pressures. The third largest producer is the United States with 10 percent of global production and 4 percent growth over the last 5 years. Note that global pork production has increased over the past 5 years. Production in 2002 was 8 percent higher than 1998. These three regions (China, EU, and US) account for 81 percent of world pork production and 80 percent of the increase since 1998. China alone accounted for two-thirds of the increase in global pork production.

Table 1. World Pork Production, 1,000 Metric Tons Carcass Weight Equivalent.

	1998	1999	2000	2001	2002p	2003f	World Share 02	Growth 98-02
China	38,837	40,056	40,314	41,845	43,000	44,100	50%	11%
EU	17,392	18,059	17,585	17,419	17,800	17,820	21%	2%
United States	8,623	8,758	8,597	8,691	8,973	8,819	10%	4%
Brazil	1,690	1,835	2,010	2,230	2,356	2,430	3%	39%
Canada	1,337	1,550	1,638	1,729	1,830	1,865	2%	37%
Rusn Fed	1,510	1,490	1,500	1,560	1,600	1,700	2%	6%
Poland	1,650	1,675	1,620	1,547	1,585	1,640	2%	-4%
S Korea	992	950	1,004	1,077	1,161	1,200	1%	17%
Japan	1,285	1,277	1,269	1,245	1,200	1,190	1%	-7%
Philippines	933	973	1,008	1,064	1,095	1,120	1%	17%
Mexico	950	994	1,035	1,065	1,085	1,100	1%	14%
Others	4,129	4,128	3,806	3,683	3,780	3,790	4%	-8%
Total	79,328	81,745	81,386	83,155	85,465	86,774	100%	8%

Source: USDA-FAS, p=preliminary, f= forecast

Brazil and Canada are the two fastest growing countries for pork production, up 39 and 37 percent, respectively over five years ago. They are also comparable in size to one another and to the Russian Federation and Poland. The two eastern European countries posted steady to lower production numbers. Countries with approximately 1 percent of world production include South Korea, Mexico, and the Philippines that are growing at a 14-17 percent rate. Japan and the remaining countries of the world collectively are reducing pork production.

Pork exports in 2002 were 37 percent higher than 1998 as pork production increased in some regions and declined in others (Table 2). The EU has the largest exports with over one-third of the total and 2002 exports were 29 percent higher than 5 years earlier. Canada is the world's second largest exporter, surpassing the US in 2000 and growing 85 percent over 5 years. The US grew 27 percent and is the third largest exporter. These three regions account for nearly three-fourths of global pork exports. Brazil and Australia are the fastest growing exporters during the period, but Brazil is a much larger player, accounting for 10 percent of total pork exports.

The EU and Canada are the largest net exporters, exports - imports (Table 3). However, Canada is more dependent on trade as its net exports are equal to 38 percent total production compared to 7 percent for the EU, 3 percent for the US, and 17 percent for Brazil. Net importing countries, those that import more than they export include, Japan, the Russian Federation, South Korea, and Mexico. For example, imports to Japan were 94 percent as large as domestic production meaning that nearly half of the pork consumed was imported.

Japan is the largest pork importer and it is a growing market (Table 4). Mexico and South Korea are smaller but rapidly growing pork importers. The five-year growth in Japan alone is larger than the entire market in Mexico, but Mexico is growing faster. While the US has transportation advantages to Mexico, it would appear that Canada and the US are well positioned for exports to Japan, South Korea, Hong Kong, and China. Canada also has an advantage over others when trading with the US.

Table 2. World Pork Exports, 1,000 Metric Tons Carcass Weight Equivalent.

	1998	1999	2000	2001	2002p	2003f	World Share 02	Growth 98-02
EU	1,004	1,390	1,470	1,235	1300	1,325	34%	29%
Canada	432	554	658	727	800	815	21%	85%
United States	558	580	584	708	709	726	19%	27%
Brazil	105	109	163	337	400	430	10%	281%
China	143	75	73	139	225	200	6%	57%
Hungary	109	131	143	118	120	110	3%	10%
Poland	220	235	160	100	80	85	2%	-64%
Australia	17	37	49	66	79	83	2%	365%
Mexico	49	53	59	61	60	60	2%	22%
Czech Rep	27	10	8	14	27	25	1%	0%
Korea	116	113	30	42	20	55	1%	-83%
Others	20	23	14	5	5	7	0%	-75%
Total	2,800	3,310	3,411	3,552	3825	3,921	100%	37%

Source: USDA-FAS, p=preliminary, f= forecast

Table 3. Pork Net Exports and Share of Production, 2002.

	Net Exports	Net Export/Prod
China	165	0%
EU	1,240	7%
United States	230	3%
Brazil	400	17%
Canada	700	38%
Rusn Fed	-700	-44%
Poland	30	2%
S Korea	-125	-11%
Japan	-1,125	-94%
Philippines	-10	-1%
Mexico	-240	-22%

NEW COMPETITION

Feed costs remain the major determinant to long term profitability. The Midwest US and the Prairie Providences of Canada are comparable in total cost of production with a slight feed cost of gain advantage to Canada (Martin and Kruja, 2000 and Brewer *et al.*, 1998). However, Brazil may have lower cost than either North American country.

Table 4. World Pork Imports, 1,000 Metric Tons Carcass Weight Equivalent.

	1998	1999	2000	2001	2002p	2003f	Growth 98-02
Japan	777	919	995	1,068	1,125	1,150	45%
Rusn Fed	710	832	520	560	700	710	-1%
United States	320	375	439	431	479	490	50%
Mexico	144	190	276	294	300	310	108%
Hong Kong	207	217	247	260	285	300	38%
S. Korea	66	156	174	123	145	150	120%
Canada	64	65	68	91	100	105	56%
China	46	43	50	58	60	70	30%
EU	40	54	54	55	60	60	50%
Romania	53	27	29	46	55	55	4%
Poland	74	55	47	23	50	50	-32%
Others	160	227	223	188	194	202	21%
Total	2,661	3,160	3,122	3,197	3,553	3,652	34%

Source: USDA-FAS, p=preliminary, f= forecast

Brazil has captured the attention of many US producers in part due to its vast grain production potential and now because of its increasing pork production. A delegation from the Iowa Pork Producers Association (IPPA) visited Brazil. (Iowa Producers Study Agriculture in Brazil - http://www.iowapork.org/export/brazil.html)

> One farm they visited was a Brazilian joint venture in Mato Grasso that currently has 12,200 sows. The company's goal is to expand to 18,000 sows by the end of the year and is projecting to reach 55,400 sows in 2005. The company's plan is to develop production pods of 10,000-plus sows with three-site production at each pod. The IPPA delegation concluded that many costs including land, labor, facilities and energy are much less expensive in Mato Grasso. The challenges faced include the country's infrastructure, instability of the currency exchange rate and increasing the domestic market. Company officials stated the farm in Mato Grasso is 1000 hectares (2,470 acres). The site provides excellent bio-security, has a natural barrier of a forest preserve, has a good supply of water, and the manure can be utilized on nearby farmland. Market hogs are transported 700 miles, with the trip lasting approximately 22 hours one-way. The company's management is focused on pork production and may consider processing at some time in the future. Currently, feed is prepared on a custom basis by a feed mill in the area and plans include the construction of a feed mill.

Given Brazil's large base of low cost land it is expected that its pork production will increase. Much of the increase will feed the domestic market, but exports are also expected to continue growing. Currently most of its exports are as frozen split carcasses to Russia, but it will likely try to expand into other markets.

LARGE SCALE PRODUCERS

The US pork industry as well as that of other countries is becoming dominated by large firms. Glenn Grimes and James Rhodes began studying the structure of the US pork industry in 1974 when the "Large Producer" was defined as marketing 5000 hogs per year. Grimes has continued to survey producers in approximately three year intervals to monitor changes in the US pork sector. The most recent survey was based on calendar year 2000 (Lawrence and Grimes, 2001). The 20 largest firms were estimated to have marketed 33.3 million hogs in 2000, nearly 35 percent of total U.S. marketings. Combined with the 136 operations in the 50,000-500,000 category, these 156 firms produced slightly more than half (51%) of all hogs in 2000. The share raised on large farms (50,000 head or more) has increased since 1997, when the 145 largest firms produced 37 percent of the hogs and the 5,000 and more hog class had 63 percent of the total.

It should be noted that at least 25 of the 136 operations in the 50-500,000 head category are producer networks owned by multiple individual farmers who finish the feeder pigs produced in centralized sow units. Each network produced and marketed more than 50,000 hogs a year, but may have been comprised of a dozen or more owners who finished the hogs on their own farms. A network is counted as a single operation in the survey because a single firm manages the sow unit and members of the network typically are under a common marketing contract.

The trend to fewer and larger hog operations is not new. Larger producers continue to gain market share, while smaller producers lose market share. Table 5 shows the change in market share since 1988 when the less than 1,000 head producers marketed nearly one-third of all U.S. hogs. This figure has declined to approximately 2 percent in 2000. The 50,000 head and larger category increased from 7 percent to over 50 percent. The 5-10 thousand group has maintained a stable market share over the 12-year period, and is the dividing line between those gaining and those losing market share.

Table 5. Share of annual hog marketings by size category, 1988-2000 (%).

1,000 hd.	1988	1991	1994	1997	2000
<1	32	23	17	5	2
1-2	19	20	17	12	7
2-3	11	13	12	10	5
3-5	10	12	12	10	7
5-10	9	10	12	10	10
10-50	12	13	13	16	18
50+	7	9	17	37	51

Source: Lawrence and Grimes, 2001

Since 1994 the 50,000+ category was divided into categories of 50-500 thousand head and those with more than 500,000 head. Both size categories increased in number of operations and market share (Table 6). Firms marketing 50-500 thousand increased from 57 to 136 operations and went from 7 to 17 percent market share. The more than 500,000 head firms increased from 9 to 20 operations and from 10 to 35 percent of market volume.

Table 6. Number and market share by large firms, 1994-2000.

	1994	1997	2000	1994	1997	2000
1,000 hd.	Number of firms			Percent of marketings		
50-500	57	127	136	7	13	17
500+	9	18	20	10	24	35

When surveyed most producers planned to grow in the future, but regardless of intentions, plans are not always followed. Table 7 compares the projections for growth by size category based on the 1997 survey with the actual change in marketings from 1997 to 2000. Notice that the less than 5,000 head groups planned expansion of 6 to 15 percent by 2000, but actual marketings decreased 20 to 27 percent. The 5,000 and larger categories also trimmed their growth plans from the 1997 projection, but still posted growth. The 10-50 thousand class was within 2 percentage points of expected growth, and the more than 50,000 category exceeded planned growth by 7 percentage points. However, some of the growth in the larger categories can be attributed to adding more operations that grew into the larger size class.

Table 7. Projected growth reported in 1997 and actual growth in 2000 by size group (%).

Marketings 1,000 hd.	Planned	Actual
1-2	+10	-22
2-3	+6	-27
3-5	+15	-20
5-10	+25	+13
10-50	+39	+37
50 and up	+41	+48

One true measure of competition is cost of production. While modern producers know their cost of production, how they calculate it can differ widely. The survey simply asks how they faired in 2000. Sixty-five to 95 percent of the firms reported a profit in 2000 and another 5 to 24 percent said they were breakeven. Note that profitability was more probable for larger producers but there was relatively little difference between 2-3 thousand and 10-50 thousand head marketed (Table 8).

Another test of competitiveness is "staying power". Producers were posed a hypothetical question about cost of production by asking producers what live hog price they would need to stay in business until 2003 if central Iowa corn price was $2.50/bu. Table 9 shows the distribution of responses. First, note that the group planning the fastest growth (50-500) had the fewest percent of operations that could produce for $34-36/cwt. However, most of these firms had only slightly higher costs—52 percent would stay in business at $39. Second, even at higher prices above $48, there were still producers who would quit the business. In fact, 7 percent of the marketings in the 1-2 group will exit by 2003 regardless of price.

Table 8. What were the financial results for producers by size category for the year 2000 (%)?

	Net Profit	Breakeven	Net Loss
1-2	65	24	11
2-3	77	15	8
3-5	79	16	5
5-10	78	13	9
10-50	77	12	11
50-500	90	5	5
500+	95	5	0

Table 9. Willingness to stay in production until 2003 by size group at each hog price if central Iowa corn price was $2.50/bu. (%).

Size class	Percent of 2000 marketings				
1,000 hd.	$36	$39	$42	$45	$48
1-2	19	43	72	89	93
2-3	22	44	71	86	98
3-5	16	37	70	91	94
5-10	17	42	78	95	99
10-50	23	52	77	93	97
50-500	4	51	86	97	98
500+	34	53	89	93	100

In rough numbers, a dime change in corn price relates to about $.50/cwt in cost of production. Currently we are closer to $2.00/bu for corn than $2.50. The $.50 lower corn price would reduce the stay-in price by approximately $2.50/cwt. Considering the cost structure of large farms and recent prices it is not surprising that the large producers are satisfied with the pork business.

The large producers are also more likely to use "non-traditional" business structures. Over two-thirds of hogs marketed by the 50,000 head or more producers were finished in contract facilities. Nearly 90 percent of their marketings are sold under contract or owned by a packer. These producers expressed a high level of satisfaction with hog production, they and contract growers were satisfied with production contracts, and the producers were satisfied with their marketing contracts and planned to continue them in the future. These 50,000 head or more producers planned to grow their business, but many noted their plan growth would be through acquisition of existing facilities. Limits to their growth included lack of profitability and, to a lesser extent, environmental regulations.

The less than 50,000 head a year producer is also planning growth over the next 3 years, but to date has been losing market share. The less than 5,000 head producers in particular have declined in number and production. Smaller producers were also less likely to use production or marketing contracts, AI, or sell on a carcass basis. However, because the smaller producers relied more heavily on the cash market, they are also more actively involved in price discovery for many of the contracts used by other producers.

CONCLUSIONS

The new competitions to traditional pork producing regions are a concern to existing producers because they have changed the rules of the game by finding and exploiting advantages. In the case of Brazil and the Prairies of Canada the advantage is low costs of grain, less dense populations, and a growing export market for pork. They are also building new systems that efficiently incorporate technologies and transportation efficiencies. The large producers of the US are exploiting many of the same factors. They developed efficient systems without the limitation of an existing farm. They can chose where to produce hogs and put sows in areas that allow for large facilities and have cheaper labor and put finishing near large grain supplies and packer demand. They also wrote a new set of business rules regarding contracts, relationships, and leverage rather than ownership, family labor, and equity. These new competitors, regardless of their location represent the new pork industry that has a global market focus and is quality and efficiency driven. Successful exiting producers will learn to play by the new rules, or find new markets that are outside the commodity pork mainstream dominated by the new competitors.

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NEW EMERGING COMPETITORS - WHAT CAN WE LEARN FROM THEM?

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ABSTRACT

This article discusses the competition that arises from new industry alignments that provide greater production efficiency, economies of scale, and traceability. It is anticipated that industry consolidation will continue and that a vertically coordinated system is required for long-run competitiveness in the pork business. To date mainstream pork production has been commodity oriented but it would seem consumers are becoming more demanding in terms of quality, value, and traceability. Thus, there is a need for new business models between producers, processors and retailers.

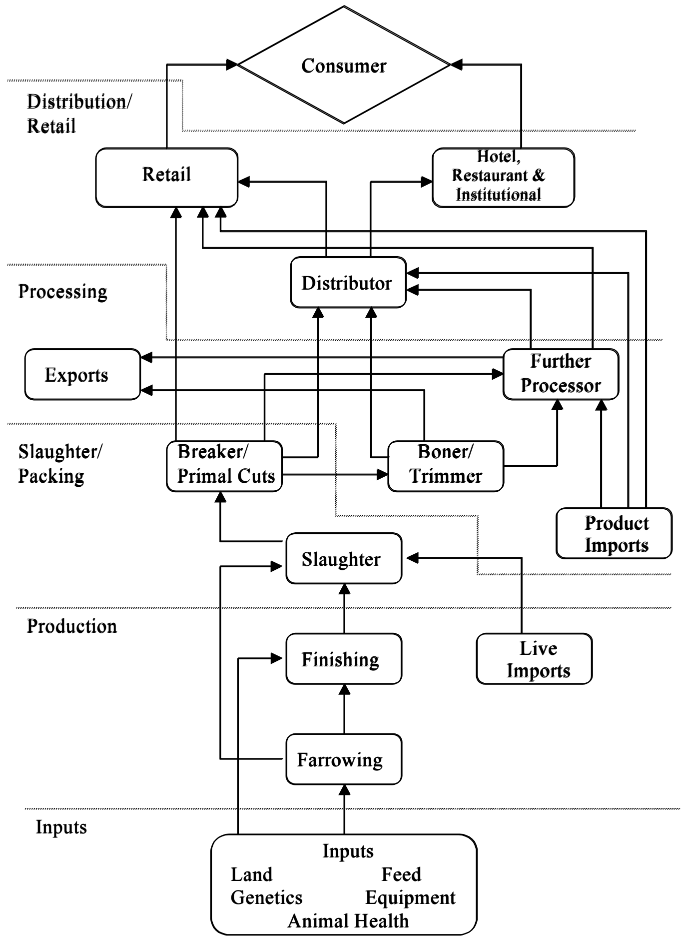
INTRODUCTION

The competition focused on within this paper is not simply new regions of the world producing low cost pork for the export market, but rather the competition that arises from new industry alignments that provide greater production efficiency, economies of scale, and traceability. Figure 1 displays the typical portrait of hog production and the marketing supply chain. There are five main shareholders in the pork supply chain and they are: producer; slaughter/packer; processing; distributor/retailer; and consumer. Until recently, these supply chain participants acted independently of each other with little information flow from one level to the next. However, there is increasing evidence that given the complexity of the industry, the degree of specialization involved, and the amount of capital required that perhaps a more vertically coordinated approach is needed if Ontario wants to avoid the risk of becoming uncompetitive.

It is important to recognize that most non-agricultural sectors are in a post-industrial revolution and that in this setting, power comes from information, knowledge, and concepts. The swine industry however, has not reached this stage and is still going through the industrial revolution. In the U.S., it is estimated that over 70% of the swine industry has adopted some form of industrialization. As with any change there are early and late adopters and it is speculated that many of the remaining 20% to 30% of the U.S. producers will struggle to have long term viability within the hog industry.

Along with this industrial process comes the irrefutable and seemingly irreversible trend of supply chain consolidation. It is now very common in the U.S. to have CR4 ratio's (i.e. the four-firm concentration ratio) exceeding 80% for many agricultural sectors (cattle 1997 - 80%). In terms of time line, it has not been until the last 8 to 10 years that industrial techniques have been applied to the hog industry. Prior to the last few years, the technology and production systems needed to gain control over diseases when large volumes of pigs were mixed together had not yet been developed. Large-scale three-site production did not move into Ontario until 1994.

Figure 1. Hog Production and Marketing Supply Chain.



Source: "Potential Impacts of the Proposed Ban on Packer Ownership and Feeding Livestock", Sparks Companies Inc., 2002.

Typical industrialized techniques for the swine industry include: three site production (i.e. sow, nursery, and finishing all at different locations); the ability to construct large sow units (i.e. 2,400 head); building finishing barns in multiples of 1,000; the use of a common genetics program for the entire sow herd; high frequency of artificial insemination; and the use of a centralized feed manufacturing system that delivers prepared feeds to barns in a 80 to100 km radius. Currently in the U.S., there is a lot of experimentation in terms of industry organization. Examples of industry alignment include: vertical integration (e.g. Smithfield Foods - 700,000 sows of which 55% are NPD genetics); vertical coordination (e.g various marketing contracts); alliances (e.g. Pipestone pork producers); and co-ops (e.g. the Illinois producer group i.e. American Premium Foods Inc.). All of these arrangements have as their end goal the desire to produce the correct type of pork demanded by the consumer, hence, lowering the overall operational risk of the production system.

If the poultry industry is used to speculate about future swine industry models, then a highly coordinated system is likely where there are no breaks in the information flow between various components (i.e. input suppliers, producers, processors and retailers). Producers in this setting have become managers of contracts. It is anticipated that as the hog industry moves into production to specifications, producers will be faced with lower per unit margins and the variability in profitability will remain large which will maintain the unusually high income to risk relationship. To date there has been little sharing of information between retailers, processors, and producers. Frequently, in many systems there is a break in the information flow and if a niche has been discovered, private business has kept the information to allow for profit maximization.

In several regions of North America (including Ontario), any restriction on the ability to decide on what genetics to use, what company to purchase feed from, what health status to maintain, and what housing system to use, would be viewed as a threat to independent pork production. However, the bundling of farm inputs to provide possibly better traceability, better quality assurance, and to allow for branding can result in increased sales volumes if properly communicated with the consumer (e.g. Danish pork). Branding is normally defined as a guarantee that pork was produced in a certain way (i.e. consistency every time). To date in Canada, while there has been much talk about meat traceability and the development of "story" pork, the majority of consumers have not demanded this level of information about the meat they consume. Still, using Smithfield Foods as an example, branded fresh pork now accounts for 40% of their fresh pork sales and continues to grow at double digit rates. The branding occurring in the U.S. is not simply what feed is used, rather it involves animal welfare, health status, genetics, food safety and value added case-ready packaging. It is now known that in the U.S., 53% of every food dollar is spent away from home and that 10% of all food consumed is eaten in a vehicle.

Given this discussion, it would appear likely that pork production in the future will be done under tight protocols and that producers, packers, and processors will band together to gain economies of scale for: accessing inputs; knowledge; and to match the scale of the forward player. The development of these food chains will have diversity i.e. producing 2 or 3 different meat products, and have the capacity to be global traders.

LITERATURE REVIEW

The summary provided below gives the reader an understanding of why the pork supply chain is consolidating and illuminates some of the challenges faced by industry stakeholders.

Competition Theory

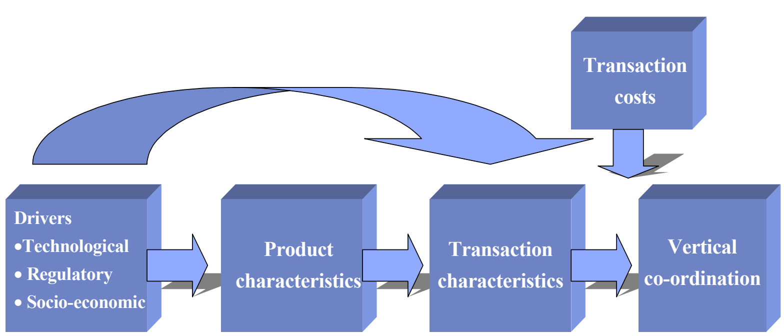
Competition theory has several implications for a discussion on structural alignment in the meat industry. First, although industry structure (i.e. number of firms and size of firms, and vertical alignment) is firmly established in the minds of many producers, legislators and even consumers as a critical indicator of whether an industry is competitive, this link is not warranted. The often implicit standard of perfect competition that lies behind the link between structure and efficiency does not constitute an operational criterion to assess performance, simply because it presumes to know more than can be known in the absence of competition. Secondly, it cannot provide us with an objective and independent efficiency standard. Even the definition of the boundaries of a market or of an industry is problematic. And this definition is necessary before market share calculations can be made in the first place.

A more helpful understanding of competition as a process rather than an outcome shifts our attention to search for artificial barriers to entry. Increasingly, competition is more about innovation, product differentiation, price-cutting, advertising, the development of personal relationships with buyers or sellers, and reputation or good will. This reorientation would prompt us to examine things like the rate at which new products are introduced or at which new uses are being found for existing products. In a trial and error competitive process, it would be expected that some products do not make the grade. Are there any discernable patterns in product pricing when the entire life cycle of a product is considered? The inelastic demand for pork (i.e. a relatively large change in price results in a relatively small change in quantity demanded), means that competition in the pork market may tend to be expressed more strongly in ways other than price.

Conceptual Framework For Vertical Coordination

Below in Figure 2 is a model which helps to illuminate our understanding of why the pork supply chain is vertically aligning itself. The key drivers to vertical coordination can be categorized into: technological; regulatory and socio-economic. Technological drivers are those that affect economies of scale and can impact on product characteristics. Technology creates economies of scale from large-scale production/processing units, or allows tighter control over product quality through feeding, housing, or management practices. These economies may encourage closer vertical coordination and industry consolidation if it is less costly for a processor to do these management functions internally rather than deal with larger numbers of small producers.

Figure 2. Vertical Coordination Model.



Source: "Vertical Linkages in Agri-Food Supply Chains in Canada and the United States", Agriculture and Agri-Food Canada.

Technology can also impact on product perishability and the introduction of new product characteristics e.g. lower pH pork.

Regulatory drivers of interest to the swine industry are liability, traceability and product standards and grades. For example, the 1990 Food Safety Act in the UK increased the legal liability of food firms, causing them to seek more information about upstream production practices in the food supply chain. In 1998, the EU endorsed plans to extend product liability laws to farmers, whereas previously agricultural producers had been exempt. The requirement for full traceability of agricultural products in the event of a breakdown in food safety may be a regulatory requirement in itself. In general, it is speculated that with the demand for increased traceability, occasional supply chain relationships will move towards closer vertical relations.

Socio-economic factors can also lead to greater vertical coordination. Changes in consumer life-styles and preferences have increased the demand for branded, further processed meals, including home meal replacements. Product quality is extremely important and is signaled by a firm's brand name. To differentiate their products, to protect the investment in their brand name, and to reduce the monitoring costs of guaranteeing the quality of their inputs, processors will prefer closer vertical relations with their suppliers. Heterogeneous consumer preferences in international markets encourage product differentiation, moving the sector away from its traditional commodity orientation and encouraging closer vertical coordination.

Product characteristics affect the transaction characteristics and thereby influence the vertical relationships that evolve. Five product characteristics that lead to greater vertical alignment are: product perishability, the amount of product differentiation, the variability and visibility of quality difference, and new characteristics of interest to consumers e.g. organic. Product perishability creates uncertainty, adds to the complexity of the transaction, and increases the negotiation cost, thus it is more likely to lead to a greater degree of vertical coordination. Similar comments can be made regarding product variability and new characteristics to consumers.

The model then looks at transaction characteristics, which can be broken down into uncertainty, frequency, asset specificity, and complexity. The uncertainty occurs over product quality, reliability of supply, price, and just the difficulty in finding a buyer, particularly if the product has unique characteristics. Asset specificity arises when one party has made an investment in a production process specific to one buyer or seller, thereby locking themselves into that relationship for a period of time. Transactions involving specific assets leave firms vulnerable to opportunistic behaviour and lend themselves to contracting or vertical integration as the choice of governance structure due to the high monitoring and enforcement costs.

Complexity mitigates against spot market transactions. Higher transaction costs are incurred in writing fully contingent contracts in situations of complexity. If the transaction costs become sufficiently high, vertical integration may occur. A strategic alliance which allows sufficient flexibility in the relationship to deal with the complexities is another possibility. In the presence of asset specificity at a high level, this results in vertical integration because of the monitoring and enforcement costs that arise in bilateral contractual arrangements or strategic alliances.

In summary, this model provides a framework to discuss and explain why vertical alignment is occurring in the swine industry. The demand for greater traceability, the incorporation of new technology such as 3 site production coupled with a perishable product plus the need for precise product specifications i.e. pork with a certain pH or colour, all leads to a more vertically coordinated supply chain. Increasingly, packer/producer and packer/retailer transaction costs are increasing because of the need for traceability and more defined meat characteristics. In addition, the capital investment and asset fixity in pig production, processing and retailing is high which leads to more vertical coordination.

RETAIL CHANGES

Similar to the producer and processor levels, retail consolidation has been occurring as well. The top 3 retailers in Canada are estimated to have market share of 60 to 70% whereas in the U.S. the top 5 have only 42%. While independent retailers and smaller chains are fast losing ground in the rapidly consolidating food retail market, in 1998 they still accounted for about $US70 billion in sales with 16% of the food retail market. However, it must be recognized that food industry consolidation will continue in the U.S. primarily driven by Wal-Mart with it's aggressive food retailing strategy of everyday-low-pricing and Supercenter concepts which will apply grow-or-perish pressure on other retailers. Smaller market retailers will continue to face fierce pricing competition.

Growing pressure from consolidating retail operations reduces margins for meat packers, processors, and others. Processors and handlers report growing competition for markets, and the recent retail consolidations have meant narrower margins in both fresh and processed products as processors compete to meet increasingly stringent retail requirements and narrowed margins. Also, large retail chains will often only consider potential suppliers that are capable of producing the large volume of product necessary for national or regional distribution. These trends, in turn, increase pressure on processors to increase their volume while at the same time reducing their costs. The pressures to reduce costs force the search for low-cost livestock supplies. Processors expect that these trends will continue and point to recent trends as evidence.

Trends toward consolidation at the consumer level have been persistent and far-reaching. In just the past few years:

- Kroger acquires Fred Meyers, forms largest retailer (1999)
- Royal Ahold acquires east coast firm, Giant Foods/Pathmark
- Wal-Mart, together with Sam's Club expands very rapidly, becoming largest retailer by 2000. Wal-Mart's food sales for 2000 are nearly three-fold the 1996 level, and Safeway acquires Dominick's.

Consolidation at retail probably is about half done, say trade analysts. The expectation is that the top five retailers will soon account for more than 50% of food sales and that consolidation will continue rapidly in the future. For a listing of the major U.S. Supermarkets and their sales volumes, see Table 1.

Table 1. Supermarket Sales and Rankings, 2000.

1999 Rank	2000 Rank	Company	Stores number	Sales bil $	Share %
7[1]	1	Wal-Mart Supercenters	862	57.2	11.1
1	2	Kroger Company	2,359	49.0	9.5
2	3	Albertsons's	2,514	36.4	7.1
3	4	Safeway	1,726	32.0	6.2
4	5	Ahold, USA	1,208	27.8	5.4
		Top Five	8,669	202.0	39.3
13	6	Supervalu	457	23.3	4.5
8	7	Publix Super Markets	645	14.6	2.8
17	8	Fleming	164	14.4	2.8
6	9	Winn-Dixie Stores	1,160	13.8	2.7
	10	Loblaws Cos.	596	13.8	2.7
		Top Ten	11,691	282.0	54.8

[1] Ranked number 4 when Sam's Club stores are included
Source: Supermarket News

Livestock quality is essential to support trends toward more branded products. Also important is the growing emphasis on new product development including items that are more convenient for consumers to use. Enhanced control over quality is essential as packers compete for financing necessary to bring new, more convenient products to markets to satisfy ever more insistent consumer demands.

Consumers now have the ability to purchase more and higher valued meat products. The largest single market for pork today is pork for further processing, representing 37.5% of 1999 sales. These products include branded lunchmeats, further processed products under the processor or retail label, or further processed products going into food service or export markets. Branded programs by packers, a rapidly growing market segment, make up 18.2% of the current market volume and in the future will represent an even larger share of pork sold. These pork products must carry a higher degree of branded reputation and liability and demand higher standards to consistently satisfy end-user expectations. Within the branded products there is expected to be a switch from further processing by other companies to one of branded retail and food service pork items by packers. While most pork is unbranded, except for processed products like sausage, ham, and bacon, some new products, like Smithfield Foods Lean Generation brand of lean, fresh pork products provide brand name quality assurances and consistency for consumers. Table 2 shows packer pork sales by retail category.

Table 2. Packer Pork Sales by Category, 1999.

Category	%
Retail grocery, non-branded	14.2
Branded, value-added products	14.2
Food service non-branded	7.8
Food service branded value added	2.3
Domestic processor for further processing	37.5
Export non-branded commodity sales	6.3
Export branded value added sales	1.7
Wholesaler or broker	11.7
Other	4.5

Source: Meat Packer Vertical Integration and Contract Linkages in the Beef and Pork Industries: An Economic Perspective, American Meat Institute, May 2000, pg. 76.

THE DANISH PORK SYSTEM

Denmark seems to have no natural advantages in hog and pork production over other countries. By all conventional input measures, Denmark appears to have a significant cost disadvantage when compared to major competitors: land is scarce and high priced, manure disposal regulations are strict, wage rates in farming and processing are well above those of other major pork producing countries, feed costs are high as a result of EU Common Agricultural Policy, line speeds in processing plants are slow and the growing markets in East Asia are distant. The continued success of the Danish hog and pork industry appears to be related to its structure, achieving strategic linkages along the marketing chain through the cooperative approach.

The striking characteristic of the Danish hog and pork industry is its cooperative structure. In the year of 2000, about 93% of total throughput in the industry was channeled through just 3 large meat processing cooperatives. The most significant industry-wide actor in the Danish pork sector is The Federation of Danish Pig Producers and Slaughterhouses i.e. Danske Slagterier (DS). It is an umbrella organization encompassing all of the Danish pork cooperatives. DS fulfils a number of roles, including representing the pork industry in consultations and negotiations with outside bodies, formulating industry-wide strategies, developing new products and services for its producers and encouraging close cooperation among all stages of the pig production and marketing chain.

DS plays a pivotal role in coordinating advances in production and processing technology, market research, and training for the pork sector. It's close links with all sectors of the pig marketing chain mean that DS stays extremely well informed about developments within the chain and can respond quickly to changes in the production and marketing environment. Perhaps one of the most unique features of DS is that because it represents many stages of the pig marketing chain, adversarial relationships between buyer and seller, which are common in the marketing chains of meat industries in many other countries, appear to be largely absent. Instead DS fosters a cooperative spirit permeating the whole Danish pork industry.

The collective strategy of the Danish hog and pork industry is not to produce a bulk homogeneous product in the largest quantity possible, but to produce a high quality, market specific, differentiated set of products. The focus is on product competitiveness rather than cost competitiveness.

In summary, the Danish industry is export oriented, vertically integrated, focused on meat quality, food safety, and quality control. In terms of cost of production, Danish pork production is estimated to be about 33% higher than Ontario's. The branding of pork which has occurred in Denmark relates to health status and rearing practices rather than genetics and feed regimens.

THE SMITHFIELD SYSTEM

Smithfield Foods is the largest pork processor in the world, with fiscal 2001 production of 6 billion pounds of fresh pork and processed meats (they process over 20 million hogs annually). They supply food service customers and retailers and own some of the most popular retail and food service pork brands in the world. Beginning in 1998, Smithfield Foods expanded beyond U.S. borders with acquisitions in Canada (Schneiders), France (Animex), and Poland. In 1999, the company further developed its international operations through a 50% owned integrated pork venture in Mexico. Smithfield Foods is the largest hog producer (12 million hogs or 3.5 times more than the nearest competitor) in the world and is committed to vertical integration to ensure a steady supply of raw materials and tame industry cycles. Through its hog raising and pork processing subsidiaries, the company can exercise complete control over its products from their genetic lines (NPD genetics account for 55% of total herd) and nutritional regimen to how they are processed, packaged and delivered to the end user. They own and operate hog farms with about 700,000 sows in North Carolina, South Carolina, Virginia, Utah, Colorado, Texas, Oklahoma, South Dakota, Missouri, and Illinois plus another 40,000 in Mexico, Brazil and Poland.

Smithfield Foods is actively attempting to expand their branded meat sales. The intent is not simply to sell commodity fresh pork, but rather to improve profitability by achieving parity between branded value-added fresh pork and high-value processed meats. In fiscal 1994, the Company's subsidiaries produced about 660 million pounds of processed meats. In fiscal 2000, the total was more than 2.2 billion pounds. The value-added branded labels used by Smithfield include: Lean Generation, Smithfield Premium Tender'n Easy, John Morrell Tender N Juicy and Gwaltney Tender Perfection. Branded fresh pork now accounts for 40% of the fresh pork available for branding which is triple the percentage of four years ago. Case-ready sales volume have also increased substantially with Wal-Mart their major customer (52 million pounds in 2001 in over 40 states). Some of the stated benefits of case-ready are: freshness, food safety, and substantial cost reduction. Smithfield feels that the growth of their branded, case-ready and value-added fresh pork sales lessens their exposure to the commodity side of the business.

In summary, clearly Smithfield is moving quickly away from commodity fresh pork to branded case-ready product or processed meats. Currently, the Smithfield strategy is to gain market clout by reducing their vulnerability in the pork commodity markets and gain consumer loyalty for their brand products thus gaining greater supply chain power over both independent producers and the major retail chains.

IMPLICATIONS TO THE ONTARIO INDUSTRY

Clearly with the amount of industry consolidation occurring throughout the entire North American supply chain (i.e. producer, packer/processor, and retail levels) it will be very hard for independent producers to differentiate, brand, and develop new products to gain much market clout. While recent economic literature states that industry structure (i.e. number of firms) is not that important to industry competitiveness, it still seems difficult to conceive how independent producers will offset the market power of a large vertically integrated firm given that individually, producers lack the scale and expertise required for new product development.

The reasons for the increasing integration observed across the U.S. industry are: (i) product quality and level of consumer services (i.e. anticipate consumer preferences and translate these into animal and product specifications); (ii) operating efficiency i.e. the industry's large investment in fixed assets must operate near full capacity to hold down costs; (iii) manage risks; and (iv) gear their capacity to work with large, growing and efficient retailers in providing affordable and/or desirable products for consumers. Given these reasons for increasing vertical coordination the fundamental question becomes "How can Ontario build a vertical coordinated system?". It would seem that independent producers and packers must give up some of their individual autonomy or risk being either dictated to in terms of how and what to produce or worse being shut-out of the market place by a system that can provide the volume, quality, traceability, and desired meat characteristics demanded by the market. The evidence provided points toward the need to move quickly into the branded, value-added processed meat and case-ready markets.

Ontario is positioned well to move into these expanding markets, however, the current independent relationship between producers/packers/retailers limits innovation and information flow. Ontario needs to look vertically integrated to reap the benefits listed above and develop a strategy similar to the Danes of competing on products rather than commodities.

This could be accomplished in Ontario by building producer profiles and putting together marketing pods that produce hogs of similar carcass characteristics, health standards and feeding regimes. Hopefully sufficient volume could be achieved so that plant efficiencies in terms of slaughter, processing, storage and handling could be achieved. Significant investment must be made into new product development and consumer market analysis if the producers are to avoid the trap of being simply input suppliers. This will take a significant mind change by producers and packers. However, the timing is right for this discussion because producers are feeling vulnerable and processors are feeling powerless with the major retailers dictating the terms of the agreement.

Generally speaking, Ontario is not big enough nor suited for the low margin, high volume, undifferentiated commodity pork markets. Ontario packing plants are small by U.S. standards but remain quite competitive in terms of line speeds and other operating efficiencies. Therefore, are new business models possible between producers and packers to give the look and feel of being vertically integrated? Experimentation into these models is needed on an equal basis in terms of risk taking, capital investment, and human expertise.

In conclusion, the Ontario industry is at a cross roads in terms of how to position itself structurally. There is insurmountable evidence that industry consolidation will continue and that the industry must adopt a vertically coordinated look if it wants to avoid the risk of being uncompetitive. The approach of vertically integrating in Ontario is dubious from an environmental perspective. It would seem more logical to harness independent producers with similar production profiles to fit specific market needs. Significant capital investment must be done in new product innovation and market development to connect market seams to producer groups. Independent packers also appear very vulnerable because they are locked into commodity markets and are attempting to source hogs either through direct ownership or simple marketing contracts. Based on European experience, it would appear retailers are poised to assume the role of supply chain captain by dictating product specifications and developing brand labels.

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BREAK-OUT SESSIONS

CASE STUDIES ON GROUP HOUSING OF SOWS: THE ARKELL SWINE RESEARCH STATION FACILITY

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INTRODUCTION

In the winter of 2000, one of the two gestation rooms at the Arkell Swine Research Station was converted from a 108, individually fed, dry sow stall set-up to a group housing facility with a floor feeding system. Over the last eight months, we have been collecting data on behaviour, health and performance measures of gestating sows/gilts housed at different space allotments in the group housing facility. In this presentation we will provide a description of the design and management of the facility and report preliminary data on productivity, body condition and lesion scores. For comparison, a summary of similar parameters collected from sows/gilts housed in standard gestation stalls at the station is included.

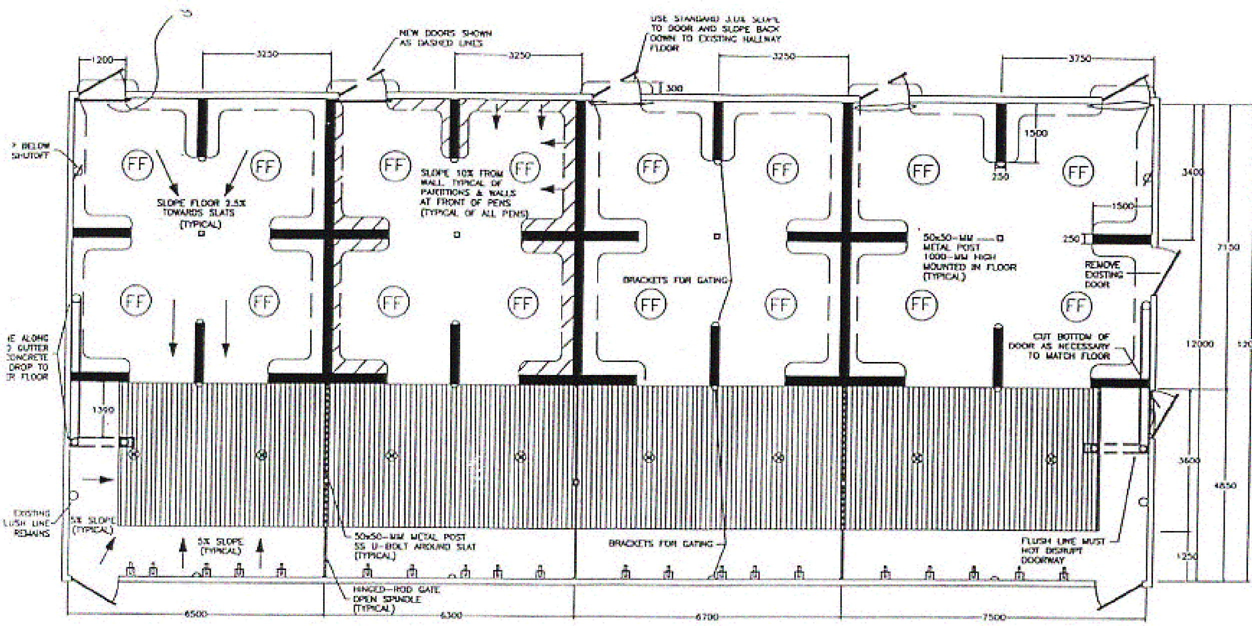
DESCRIPTION OF THE FACILITY

The group housing facility was designed with four pens ranging in size from 750 – 1015 ft^2 (Figure 1). The room had consisted of 3 rows of 36 stalls with a central alleyway and an alleyway at the back of each row of stalls. Currently, entry to each of the pens is from a central hallway of the barn eliminating any alleyways within the room and consequently, providing additional floor space in the pens.

Approximately one third of each pen has a slatted floor (dunging/watering area) where drinkers and overhead sprinklers are located. The other two thirds has a solid concrete floor that is sloped away from the walls and toward the dunging area (feeding/lying area). Cement block walls were used to separate the pens in lying/feeding area and spindle gates separate pens in the slatted dunging area. As can be seen in the figure, each pen has shorter walls jutting into it so as to divide it even further. These additional walls were designed to allow for the dropping of feed (FF) into four distinct areas of the pen to spread the distribution of feed and facilitate better access to feed for subordinate sows. The shortened walls were also intended to provide "hiding" areas for sows and to supply additional perimeter areas for sows to lie against.

The existing liquid manure system was used with only minor modifications that involved removing slats from where one row of stalls had been and joining the remaining two to form a large dunging area at the back of the pens. In order not to effect the structural integrity of the existing exterior wall, a narrow concrete area was left between the outside wall and slatted area. Originally, the nipple drinkers were placed along this wall to help keep the area wet and clean. We have subsequently added hanging drinkers over the slatted area. A timed sprinkler system was installed above the slatted area that sprays water in a twelve-foot diameter. This encourages the sows to use the slatted area for dunging.

Figure 1. Layout of the pens in the Arkell Swine Research Station group housing facility.



We have further divided two of the four pens in half, in order to accommodate smaller groups of sows held at higher space allotments. The small pens (4 in total) range in size from 370 – 535 ft^2 and the two large pens are 756 and 785 ft^2, respectively.

BREEDING AND MANAGEMENT

The herd at the Arkell Swine Research Station is a pure Yorkshire line. Sows/gilts are housed in individual crates or in small groups (3-4 animals) in the breeding room. Approximately 14 sows and a variable number of gilts are bred each week, by artificial insemination, and kept there until confirmed pregnant at 35 days post breeding. Groups comprise either first parity gilts or mixed parity sows. After mixing, they are held in static groups until they are moved to the farrowing rooms.

For the purpose of this study, groups were mixed when the appropriate number of animals needed to form groups at the various space allotments had been confirmed pregnant. It is important to understand that accommodation of the three different space allotments requires that groups be of different sizes. The three space allotments that are being tested are 25, 30 and 35 ft^2 per animal. Group sizes range from 12 to 16 animals in the small pens and from 22 to 31 in the large.

Pelleted feed is distributed once a day (8-8:30am) by a drop feeding system into 2 separate piles (small pens) or 4 separate piles (large pens). The feed hoppers above the drop are adjusted according to group size to provide 2.5 kg/sow/day of the dry sow ration.

DATA COLLECTION

Sows/gilts are randomly assigned to the group housing or dry sow stall facility. They are housed in the group system for a maximum of 70 days at which time they are transferred to the farrowing wing. All sows/gilts are weighed and scored for body condition going in and out of the gestation housing. Body condition (ranging from 1-5) is scored closely following the scoring system described by Patience *et al.* (1995) (Table 1). Skin integrity is scored once they enter the facility, 24 hours post-mixing and on a weekly basis thereafter, for animals in groups and in stalls. A scoring system for lesions, abrasions and callouses was adapted from Hodgkiss *et al.* (1998) and de Koning (1984) (Table 2). Twenty-one body regions are examined: face, each ear, snout, chest, neck, each shoulder, each side of the loin and hip, the back, udder, hind, tail, vulva, and all legs. Qualitative features such as severity or 'age' (old or fresh wounds) are not documented. Production data are also being collected and include: number of liveborn piglets, number of stillborn piglets, number of mummies and average piglet weight at birth.

Table 1. Scoring system for body condition (Patience et al., 1995).

Score	Pelvic Bones	Loin	Ribs
1-Emaciated	Very prominent. Deep cavity around tail head.	Vertebrae are prominent and sharp. Very narrow loin. Hollow flank.	Individual ribs are very prominent.
2-Thin	Obvious with slight cover.	Narrow loin. Flank rather hollow. Slight cover on spine, but prominent vertebrae.	Rib cage less apparent but individual ribs easily detected with slight pressure.
3-Ideal	Covered but felt with pressure.	Spine covered and rounded.	Ribs are covered but can be felt with pressure.
4-Fat	Only felt with firm pressure. No cavity around tail.	Difficult to feel vertebrae. Flank filled.	Rib cage not visible and difficult to feel.
5-Obese	Impossible to feel and huge fat deposits (hanging skin/fat).	Thick fat cover, impossible to feel bones. Flank full and rounded.	Thick fat cover, not possible to feel ribs.

Table 2: Definitions of skin integrity scores.

Scratches/lesions

0 - Skin unmarked; no evidence of injury
1 - < 5 wounds
2 - 5 to 10 wounds; some skin is untouched
3 - >10 wounds; Area covered with scratches/wounds with little or no untouched skin.

RESULTS

Data collection is ongoing and only preliminary results are reported here. Production data for the different space allotments are combined and averages are presented for sows and gilts in the group housing system and dry sow stalls in Tables 3 and 4, respectively.

Table 3. Averages and standard errors of data for parity-one gilts in the group housing system and dry sow stall room at the Arkell Swine Research Station.

	Group		Stall	
	n	Mean ± SEM	n	Mean ± SEM
Change in body condition score	44	0.0 ± 0.06	44	0.4 ± 0.07
# liveborn piglets	38	9.0 ± 0.57	41	8.3 ± 0.44
# stillborn piglets	38	0.3 ± 0.1	41	0.1 ± 0.05
# mummies	38	0.9 ± 0.17	41	0.8 ± 0.15
Birth weight of liveborn (kg)	37	1.5 ± 0.05	40	1.5 ± 0.04

Table 4. Averages and standard errors of data for mixed-parity sows in the group housing system and dry sow stall room at the Arkell Swine Research Station.

	Group		Stall	
	n	Mean ± SEM	n	Mean ± SEM
Change in body condition score	134	0.0 ± 0.05	32	0.0 ± 0.07
# liveborn piglets	118	10.2 ± 0.26	28	9.8 ± 0.60
# stillborn piglets	118	0.3 ± 0.05	28	0.1± 0.06
# mummies	117	1.2 ± 0.14	28	1.0 ± 0.29
Birth weight of liveborn (kg)	115	1.6 ± 0.02	28	1.5 ± 0.04

The average body condition scores when entering the group housing facility are 3.5 ± 0.07 and 3.6 ± 0.08 for sows and gilts, respectively. Overall, there is little change in body condition for sows in both group housing and stalls and for gilts in group housing. Gilts in stalls tend to show an increase in body condition by the end of gestation. Data on litter sizes and piglet body weights are similar for the two systems.

Very few animals have died or been removed from the group housing facility (Table 5). It is generally much easier to identify lame or sick animals in loose housing, since changes in their activity patterns are more obvious than for animals in stalls.

Table 5. The numbers/percentages of sows and gilts combined that have been removed from gestation facilities for various causes.

	Group (N=180)		Stall (N=79)	
	n	%	n	%
Open	14	7.8%	5	6.3%
Dead	1	0.6%	1	1.3%
Aborted	3	1.7%	1	1.3%
Culled	2	1.1%	0	-
Lame	2	1.1%	0	-
Euthanized	1	0.6%	0	-

As might be expected with the group sizes held in our system, the most severe scratches and lesions are usually found the day after new groups are mixed. Twenty-five percent of the sows scored in our system have moderate to severe scratches on their shoulders when scored 24 hours after the group is formed. By two weeks post-mixing, most of the wounds have healed and by the end of the first month and for the remainder of gestation, fewer than 5% show evidence of shoulder injuries due to fighting. There was an increase in shoulder lesions in one group housed at 25 ft^2/sow at 7 weeks post-mixing. This coincided with the removal of several animals which may have resulted in new outbreaks of fighting to re-establish dominance order in the group.

To date, vulva biting has not been a problem in our facility. Mild superficial scratches have been recorded on 31 (out of 180) animals in groups but similar lesions have been recorded on 3 (out of 79) animals in stalls, suggesting that the cause may be from some aspect of the physical environment rather than other sows. Actual bite marks have been observed on only 2 (out of 180) animals in the group housing system, but even those lesions were classified as minor.

CONCLUSIONS

To date, the productivity of sows and gilts in this group housing system is comparable to that of sows and gilts in the same herd that are held in stalls throughout gestation. The manager and staff of the Arkell Swine Research Station are very satisfied with the performance of the system (Romahn, 2001). They find the sows to be calm, clean and healthy, with reduced labour input.

ACKNOWLEDGEMENTS

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GROUP HOUSING FOR SOWS

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ABSTRACT

In 1994, Heronbrook Farm decided to change its focus from an on-site 440 Sow Farrow-to-Feeder pig enterprise to a two site 950 Sow Unit. A 2400 head Nursery barn was constructed on an adjacent farm and the existing sow barn was remodeled to accommodate the extra sows. The existing nursery/grower rooms lent themselves very well for conversion to farrowing rooms, but the need to construct a building to house approximately 400 sows in gestation became evident. The existing breeding room housed 70 sows and this would be ideal for one weeks breeding; the sows would then be moved before the critical fourth day to the existing gestation barn. This barn had 288 stalls, and this would allow six weeks for the sows to settle, and was ideal for carrying out heat and pregnancy checks before moving them into the final dry sow accommodation.

For some time, I had been concerned about the impact of the animal welfare issues being raised in Europe as well as in North America. I was also concerned that in our own barns, our gilts have always been raised, bred and housed in group pens, and have always been far more contented and quieter than the sows in gestation stalls. At feeding time the gilts are curious and interested, the sows are very loud, aggressive and agitated. Stereotypical behaviour was quite often evident. Licking, bar biting, scratching, and dog sitting were a few of these behaviours observed. We began to ask ourselves if there was an alternative housing system available that would be economical, practical, easily managed and would address the animal welfare issues that were being raised at the time, namely that the animals should be able to turn around, and be able to exhibit its natural behaviour such as rooting, co-mingling, etc.

The design that we implemented was one of my original drawings, but at the time I was fortunate enough to attend a seminar that Dr. Peter Brooks was presenting, and I had the opportunity to show him my plans and get his input. He invited me to England to visit some extensive housing systems with a number of different feeding systems. Although I was very impressed with the systems we saw: large strawed yards with Electronic Sow Feeders, I could not justify the building costs of creating such a system in Ontario. Keeping the information in mind, 35 square feet per sow, I took a look at the square feet per sow required for a stalled barn in order to get an idea of what square footage we were competing with. A dry sow stall 2’ x 7’ equals 14 sq ft plus front passage of 3’ shared, and the back passage of 2’ shared giving a total of 19 sq ft/sow. Would this be enough? I surmised that if 25 sows were in a group, then it would generate some surplus space because of the multiple affect. I thought it would be helpful if the sows were divided in to two groups per week, so that the smaller sows were grouped together, and the older, larger sows were grouped together in an attempt to reduce fighting or bullying when creating the initial groups.

Our genetics at the time were a maternal animal that included Large White, Landrace, and Duroc and exhibited tremendous leg, bone and hoof quality. Due to these traits I had very minor reservations about the ability of the sow to handle a more extensive housing system. The feed intake of these sows was voracious, and her ability to maintain condition was without question.

Taking all this information into consideration, I came up with the present design of 16 pens 16' x 28' with 16' of solid concrete at the front of the pen and 12' of slats at the back (Figure 1). The feeding system comprises a flex auger with a 3 x 50 lb drop feeder located in the middle of the solid flooring of each pen. We went with a naturally ventilated barn, with solid side panels, each panel with a window and automatic chimney ventilators. We use approximately half a small bale of straw per day for bedding and this gives the sows just enough to have something to chew and be contented.

This barn was built in 1996 and performed better than we could have expected. The level of fighting on entry was virtually non-existent, removal of sows from the pens due to poor conditioning - either getting too fat or too thin- was less than 5%. There was little variation in farrowing rate or numbers born alive, but we did see an improvement in the farrowing process as a result of the sows having more exercise.

CONCLUSIONS / OBSERVATIONS

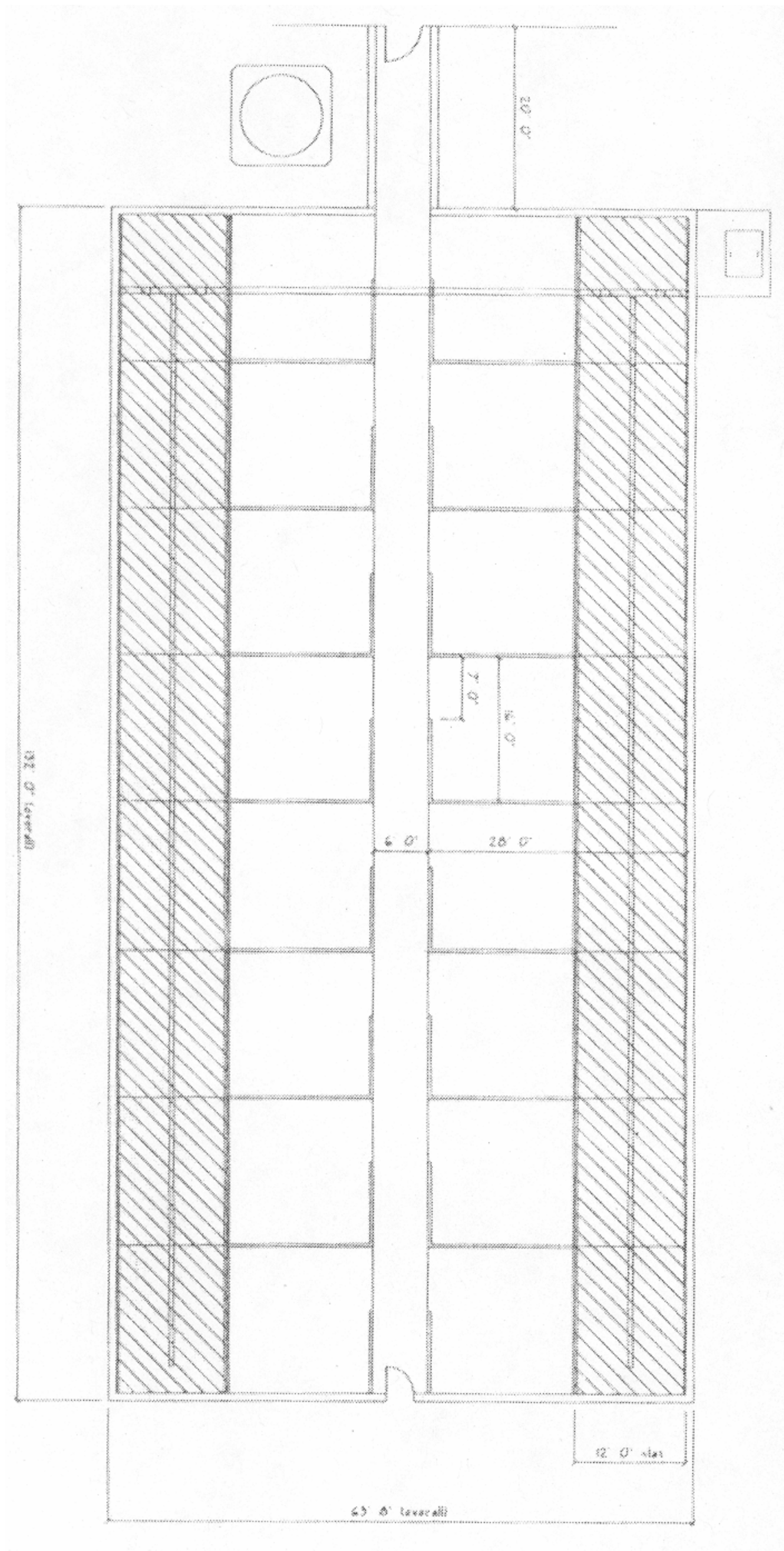
In 1998, our genetic supplier changed the composition of the maternal line, removing the Duroc portion of the equation. This has demonstrated itself in a female that is finer boned, less hoof development and more prone to lameness, therefore not being suited to an extensive housing system. Consequently, a higher percentage of sows have to be removed from the loose housing. Also, when sows are stiffer or lame, they will defecate and urinate upon rising, rather then follow the group instinct of keeping a good manure pattern. The solid floors in the pens have a 1% slope, so if the sows do urinate in the wrong place it does not run off and encourages poor manuring habits. The recommended slope is now 5%.

The natural ventilation has created excellent air quality with a very quiet barn. This could be improved, however, by incorporating dual ventilation. On very cold days in Jan./Feb., we get too much down-drafting from the chimneys over our central passage. The wide centre passage has made animal movement very easy and has removed the stress of moving and/or grouping sows.

Management of sows in this system is easy: vaccinating, and preg-checking for instance. The 19 sqft that I calculated is the absolute minimum. The recommended number of 25 sqft is probably more appropriate, and would still be cost effective in comparison to stalled systems.

Introduction of some organic material, hay or straw, has been advantageous but probably not necessary. The drop feeding system has worked well and is simple to adjust and operate.

Figure 1. Layout of the pens in the Heronbrook barn.



TOOLS FOR DECISION-MAKING IN MARKETING HOGS

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ABSTRACT

This paper considers some of the factors relevant to maximising revenue when marketing hogs, the sources of information related to those factors, and some topics concerning the interpretation and use of information. It reviews some of the tools available to help make profitable marketing decisions.

INTRODUCTION

After the job of raising a hog is done, whether or not a profit is made may depend on the final step: marketing. We all know that cost of production is a key component of the profitability of any operation. The other side of the profitability equation is revenue. Maximising revenue is as worthy a business pursuit as reducing cost of production.

The carcass weight targeted by a grading grid primarily determines when hogs are marketed. A variety of factors, from pig variation to space requirements to holidays, influence shipping practices resulting in a less-than-perfect fit with the grading grid's target range. Some of these factors can be controlled or managed to maximise financial returns.

MAKING INFORMED DECISIONS

Market Information

Most producers in Ontario will be familiar with the swine budgets in OMAF's Pork News and Views Newsletter, and the weekly Hog Market Facts[1]. Ontario Pork's website currently has a page devoted to sources of market information[2]. Their site also provides information on forward contracts, price determination, and historical sales data among many other relevant topics, as well as the Online Information Knowledge Database that allows producers access to their own data online.

These and other sources of market information provide the basis for making decisions involving feed or hog prices, and so on. I won't elaborate on these resources - the need for such essential information is obvious. Basing shipping decisions on predictions of weekly rises or falls in hog price is also outside of the scope of this paper.

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[1] The swine budgets and the Hog Market Facts are prepared by John Bancroft, Swine Grower-Finisher Specialist, OMAF.
[2] http://www.ontariopork.on.ca/ProducerInfo/marketinformation.htm

Grading Grids

There are a number of grids available, and choosing one that suits the pigs (performance capacity) and producer (shipping flexibility, potential premiums, etc.) requires weighing options as well as pigs.

Two computer software tools that can incorporate grid data and allow comparisons relevant to a particular operation are the "PorkMaster" software[3] for the PC, from the Department of Animal and Poultry Science, University of Guelph, and OMAF and Ridgetown College's "Finishing Sense" Returns Model, also for the PC. Both programs allow the input of new grading grids, calculate the effect on revenue based on entered values for market price, feed costs (based on phase feeding), and animal performance, etc. PorkMaster has the ability to evaluate the effect of variation in carcass characteristics, including sort loss (discussed in the next section). The Returns Model incorporates premiums that grids may offer, and a number of other factors, but does not currently model variation.

Sort Loss

Loss of revenue is incurred when carcasses miss the grading grid's targets for lean yield or weight. Unfortunately the value of this loss isn't itemised on the settlement statement, but it can be estimated by tallying the numbers of carcasses on the statement that didn't fit into the target and calculating the resulting revenue missed. This will also illustrate that even if the average weight and average lean yield of a group appear to hit the target, many carcasses may in fact lie outside it. While an average weight for a pen may seem adequate for shipping, it's important to remember that carcasses are graded individually.

It has been suggested that in herds where weights are closely monitored, and hogs are shipped weekly, the standard deviation of carcass weights should be around 4 kg, so that 66% of carcass weights should fall within plus or minus 4 kg of the average weight (de Lange, 1997). Many grids (but not all, especially certain newer ones) will accommodate biweekly shipping without penalty as long as weight is accurately monitored. With a narrow grid, accurate weekly shipping can be very important.

To minimise this source of lost revenue, careful attention needs to be paid to the grading grid in effect, and knowledge of the shipping weight necessary to achieve the best possible fit with the targeted carcass weight and lean yield. This in turn requires an understanding of the growth characteristics of the pigs and the dressing percentage at the packing plant. This information can be developed only by a routine review of shipping weights and the resulting settlement statement. Knowing how shipping weight affects carcass weight and lean yield enables effective adjustment of the shipping strategy. Obviously, getting the shipping weight right is a fundamental starting point. There is always variation in a herd, but here is where it can be managed, at least to some extent. Grading grids use a sharp cut-off, not a gradual one, and hitting the next higher weight class could mean a loss of 10-14 points (using the Ontario Grid as an example). This translates directly to lost revenue.

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[3] See: http://www.aps.uoguelph.ca/~porkm/

The first tool to have on hand in order to obtain this objective is, of course, an accurate weigh scale. In addition, the "Hog Target Weight Calculator"[4] is a tool for quickly determining the required shipping weight depending on the target carcass weight and dressing percentage. It can also be used to see what carcass weight is likely to result from shipping hogs at a given live weight, or to see what effect a change in dressing percentage (which may result from extended transport times) might have on carcass weight.

Accurately weighing pigs prior to shipping can result in greater returns than possibly any other manual effort in pork production. Hiring a neighbouring student to spend a few evening hours weighing and marking could produce a fine return. From a survey of 34 pork producers in Kansas, the estimated return on one employee spending 2 hours per week weighing market hogs ranged from US$41.53 to US$190.38 per hour, depending on the sort loss to begin with (Keeler *et al.*, 1994). Automatic sorters are another approach.

Carcass quality can also be affected by handling decisions - shipping time is not the time to take chances with the investment already made in a finished animal. Relevant resources are the "Should this pig be transported?"[5] and "Caring for Compromised Pigs" publications from Ontario Pork.

Marginal Feed Cost and Marginal Return

After pigs have reached the minimum weight demanded by the grading grid, another consideration may be whether or not it is profitable to continue to feed to higher weights. This is particularly important when feed cost is high, and more so if market prices are also low. It also assumes that the main driver is not the need to free up the facilities for incoming animals. In order to make an informed decision, good information is needed on the feed conversion ratio (FCR) of the herd over the relevant weight range (in addition to the change in lean yield discussed earlier). This is important since conversion normally declines as animals get larger, and can really only be estimated with any accuracy by measuring it in the barn. Once this information is in hand, incremental calculations of the added cost of feed (the marginal feed cost) and the added value of the carcass (the marginal return) can be made, and the point where profit peaks can be determined.

While the calculations can be done by anyone handy with a pocket calculator or spreadsheet and comfortable with the math, there are tools available to make it easier. The PorkMaster and Returns Model programs mentioned earlier can both help with this question, although in different ways. As described already, PorkMaster can help interpret the impact of variation in carcass characteristics on the results, but the incremental calculations must be done step-by-step. The Returns Model, on the other hand, ignores variation but automatically iterates over a range of market weights while accounting for changes in cost of feed and carcass value. I have run a number of scenarios in both programs and the results are essentially the same. Besides being a mutual confirmation of the validity of the two models, this result suggests that either program could be used to evaluate marginal cost questions[6].

[4] Supplied at the conference; available from OMAF.
[5] Available at http://www.ontariopork.on.ca/issues/animalcare/decisiontree.pdf
[6] We hope to join these two complementary programs at some time.

Another tool for the hard-core spreadsheet buff is the BEAR2000: Budgeting Enterprises and Analysing Risk program from OMAF. BEAR2000 is a powerful Excel template for analysing the financial aspects of a number of different agricultural operations. It does require some commitment in setting up the enterprise data.

"Tail-enders"

Another important question that has not been adequately modelled (to my knowledge) is the problem of when to move light pigs at the end of a batch. This is particularly relevant to all-in/all-out systems. Is it worthwhile keeping these pigs, or moving them to a separate facility for finishing? The latter is certainly necessary to reduce disease transmission to newcomers if the space is needed for incoming pigs. Nevertheless, are the economics valid? Good record-keeping will provide the answer here as elsewhere - are these pigs "tail-enders" because they got a slow start, or because they are poor performers and trying to get them to finish weight is throwing more feed away? They may cost more than they are worth, especially if they tie up space. The best strategy may be to arrange to ship on two separate grids to accommodate another degree of variation in the herd.

CONCLUSIONS

The information required for making good marketing decisions, and the advice and tools for interpreting the information, are all available. Putting it all together is worth the effort.

Niche marketing gets a lot of attention these days. There is one niche available to every producer, with little risk and modest effort required - providing carcasses that fit into the highest possible index score on the relevant grading grid. Shipping weight is under the producer's control, and lean yield is to some extent if the factors determining it are understood. So is pork quality, as affected by handling and transport and pre-shipping feeding strategies. The potential impact on revenue is very great.

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MAKING INFORMED DECISIONS ON MARKETING

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While there are several marketing options and programs available to Ontario hog producers, currently they are all based on the same principles. These principles include an USA based formula price, a grading grid based on weight sort and a yield % calculated on fat and muscle measurements in the loin. Index values are applied against the base price that will reward or penalize each hog depending on the weight and yield % category that the hog falls under. Additional premiums or discounts may be applied depending on the weight sort, muscle and or fat depth as well as special delivery times (i.e. Sunday night delivery), etc.

Before any marketing options are considered, you need to determine the needs of your hog operation and review what is currently happening. Some areas that one should look at include the weight of the hogs being shipped with respect to the weight classes of the grid. Examine the degree of variability shown by your hogs within that grid. Determine the genetic potential of your herd and review your feed program to ensure you are feeding to maximize your returns and to maximize the genetic potential of the hogs. Most importantly, you need to know your cost of production (per kg of pork produced) vs. your returns (per kg of pork produced). If the costs to maximize the premiums of the grid are greater than the income received for that grid then one must re-examine the marketing option being used.

When looking to make any changes to your marketing program or how you raise your hogs, it is important to review what your current marketing plan is telling you. For example: Currently only 60% of your hogs are hitting the target weight area as defined on your grid. Out of these hogs within the defined target weight, only 40% are earning the available premiums. Is this acceptable and if not, then why? From here, you need to establish a benchmark that will represent the basis for the marketing goals of your operation. That new target may be 80% of your hogs hitting the target weight and 70% of those hogs in the target weight receiving the premiums.

Once you have set your benchmark, you need to examine if your current program will achieve the set standards or will you need to look at a new program. Your hog operation may be restricted by limited finishing room, feed or genetic constraints or other factors that may eliminate the option of a heavy grid program. For logistic reasons, bi-weekly shipping or all in/all out facilities may require dual marketing options or selection of a grid with wider target weights.

Once you achieve your goal of 80% or more of your hogs hitting the target weight, either by weighing or sourcing a wider grid, you will need to determine how many hogs are receiving the highest index values available. In the case of premiums and discounts, one must compare premium gains against the losses attributed to lower quality hogs that are discounted. A worse case scenario can have each hog receive a zero or negative value to your bottom line.

Avoid making marketing decisions exclusively on averages. Review the degree of variability within your market hog shipments. Often you will notice that only 40% to 50% of your hogs are receiving a premium, even though your average for the hogs have great averages for weight, muscle, fat and yield %. Unfortunately, averages can mask major variability issues within shipments. For example, see Table 1:

Table 1. Variability chart.

	Weight	Muscle	Fat
Hog A	84	49	22
Hog B	92	65	11
Hog C	99	72	28
Average	91.7	62	20

While variability will always be a factor in livestock production, the challenge will be to minimize the highs and lows. Producers using consistent genetic sources and solid feed and management programs appear to have a higher rate of success meeting the goals of tighter weight sorts and reduced carcass variability within their operations.

Finally, it is important to know your cost of production per kg of pork produced. Knowing your feed conversions and hog growth characteristics by graphing your fat/muscle/yield vs. weight of hogs should help you to determine your best rate of return. Table 2 shows a comparison of an 80 kg and 90 kg hog. Table 3 contains the actual weight and gradings the comparison is based on.

Table 2. Hog Comparison - 80kg and 90kg hog (Conestoga grid).

	80 kg		90 kg	
Yield class	per carcass	per kg	per carcass	per kg
1	$122.76	$1.53	$142.30	$1.58
2	$109.55	$1.37	$141.09	$1.57
3	$108.48	$1.36	$134.89	$1.50
4	$105.27	$1.32	$137.48	$1.53
5	$102.06	$1.28	$120.26	$1.34
6	$91.35	$1.14	$115.44	$1.28
7	$91.35	$1.14	$108.21	$1.20
Average:	$104.40	$1.31	$128.52	$1.43

Based on August 26-30/02 pricing; PW Mon to Fri @ 103% $133.82.
Includes all premiums/discounts.

Table 3. Actual weights and gradings for hog comparison in Table 2.

Hog Weight	Yield Class	Yield %	Fat	Muscle	Index	Premium* or Discount
80 kg	1	64.6	10.0	54.5	110	$5
	2	63.3	12.5	56.5	107	($5)
	3	60.8	18.5	65.5	106	($5)
	4	58.2	23.0	52.5	103	($5)
	5	57.1	24.5	44.5	100	($5)
	6	55.6	29.0	44.0	90	($5)
	7	54.0	36.0	46.0	90	($5)
90 kg	1	65.1	11.0	75.0	114	$5
	2	62.3	16.0	66.0	113	$5
	3	60.0	18.0	56.5	112	$5
	4	58.4	24.0	62.0	110	$5
	5	57.1	27.0	57.5	104	($5)
	6	55.4	29.0	40.5	100	($5)
	7	54.6	35.0	51.0	94	($5)

* muscle must be ≥ 60mm to get $5.00 premium

If you cannot make your objectives for the program you are currently shipping on, and switch without being prepared to make management changes, odds are your results will probably end in disappointment. While the primary goal for choosing a marketing option is to maximize your farm gate returns, there are other factors to remember. Consideration for location, price options (i.e. fixed pricing, forward pricing) or ledger style pricing mechanisms may also be a necessity, especially for new producers. The flexibility, comfort level and trust with the packer are all part of the puzzle that should help to provide the hogs and quality of pork necessary to ensure the longevity and sustainability for both the producer and packer in Ontario.

CURRENT MARKETING OPTIONS FOR MARKET HOGS IN ONTARIO

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Since direct contracts were introduced as marketing options in the mid-nineties for Ontario hog producers, we have seen processors and producers refine the terms and conditions of the contracts being offered. Over that time period Ontario pork producers have been exposed to dozens of different terms and conditions as the processors and producers tried to maximize their returns by producing or procuring hogs that best suited their end users. This has resulted in contracts leaving the old-style single grading grid based on only the weight and backfat as the one price setting mechanism. Today the grading of hogs in Ontario is still based on the weight and backfat of each animal but direct producer-to-packer contacts has allowed more custom grading grids to be offered as each processing plant tries to select the hogs best suited for their market. See Figure 1.

Figure 1: Distribution of hogs by weight and yield class

PERFORMANCE OF HOGS SHIPPED — Producer#: 000000000

DISTRIBUTION OF HOGS BY WEIGHT AND YIELD CLASS — Sale Date : mm/dd/yy

Ontario

Weight Class / Yield Class	0.0 to 64.9 Kg	65.0 to 69.9 Kg	70.0 to 74.9 Kg	75.0 to 79.9 Kg	80.0 to 84.9 Kg	85.0 to 89.9 Kg	90.0 to 94.9 Kg	95.0 to 99.9 Kg	100.0 to 104.9 Kg	Totals Yield Class: Your Hog #	Your Hog %	Prov %
64.30-100.00	10	50	98	108	112	114	112	110	106			
(1)				**3**	**14**	**58**	**11**			**86**	6.8%	2.1%
61.80-64.29	10	50	97	106	111	113	112	109	106			
(2)			**1**	**8**	**97**	**252**	**98**	**5**	**1**	**462**	36.5%	20.6%
59.60-61.79	10	50	92	90	109	111	109	105	102			
(3)			**2**	**3**	**71**	**284**	**122**	**6**	**1**	**489**	38.6%	38.9%
57.70-59.59	10	50	88	100	105	109	105	101	97			
(4)					**24**	**103**	**39**	**2**		**168**	13.3%	25.1%
56.10-57.69	10	50	85	95	100	104	100	96	90			
(5)					**3**	**19**	**25**	**3**		**50**	3.9%	9.6%
54.70-56.09	10	50	82	93	95	95	92	88	84			
(6)						**4**	**3**			**7**	0.6%	3.0%
20.00-54.69	10	50	80	86	90	90	82	80	80			
(7)						**3**	**1**			**4**	0.3%	0.7%
MARKET HOGS BY WEIGHT CLASS												
Your Hogs	**0**	**0**	**3**	**14**	**209**	**723**	**299**	**16**	**2**	**1,266**		
Your Hogs - %	0.0%	0.0%	0.2%	1.1%	16.5%	57.1%	23.6%	1.3%	0.2%	100.0%		
Your Avg Index	0.0	0.0	93.3	107.4	111.2	111.9	110.0	95.9	70.0	111.0		
Prov - %	0.1%	0.2%	1.3%	7.1%	28.6%	40.5%	17.3%	3.9%	1.1%			100.0%
Prov Avg Index	10.0	50.0	92.4	104.9	110.0	110.4	108.4	94.2	70.0			107.9

The use of custom grading grids has meant Ontario hog producers have many marketing options for their hogs. Producers must weigh the many different options before deciding on which contract(s) to enter into. The marketing contracts for hogs are not static and the options available are ever changing.

Currently in the province of Ontario there are over a dozen contracts available to producers. These are based on different weight classes, yield classes, loin eye depth premiums/discounts along with other pricing mechanisms.

Below are some of the options currently available:

Note: Weight Class & Yield Class premiums and discounts can be used alone or in conjunction with each other when calculating the final grading index.

Weight class (HCW)
Premiums (index over 100) start at 75.0 kgs and can be obtained until 110.0 kg.
Discounts (index less than 100) are used through all weight classes.

Yield Class (backfat in mm also shown as being converted to muscle)
Premiums (index over 100) start at 40 mm back fat or 54.7 % yield of muscle.
Discounts (index less than 100) are used through all yield classes.

The quick calculation of loin-eye depth has made possible the inclusion of premiums and discounts in the payment of hogs.

Loin Eye Depth (it is used in conjunction with mm of back fat)
Premium starts at 54.9 mm.
Discounts start at depth less than 49.9mm or greater than 75.0 mm.

Pricing Premium (is on a sliding scale determined by the weekly pool price for hogs)
Ranges from $1.50 per hog when the weekly Ontario Pool price is greater than $200.00 ckg/HCW to $3.50 per hog when weekly price is less than $149.99 ckg/HCW.

Pork producers can log on to Ontario Pork's secure Online Information Network Knowledgebase site (OINK) for the latest market, contract and grading information (http://www.ontariopork.on.ca/). This site enables producers to retrieve & download their own grading and carcass health data along with a host of other industry information. The site also offers producers several different management tools that can be used in making timely and informed decisions on their marketing options.

HANDS ON HEALTH MANAGEMENT

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CASE STUDY

700 sow farrow-to-finish operation in Indiana, March 22, 2002.

HISTORY

Bruce owns a 700 sow farrow-to-finish operation in Indiana. It is a family operation. Bruce has five young children. To date, Denver, his 3-year-old son, is destined to be a pork producer. Denver will grab hold of the pen gates and scream if you try to take him out of the barns.

Bruce was primarily concerned because an increased number of sows and gilts were aborting. Recently, three sows from a group of 20 had aborted giving him a 15% abortion rate for that group. Additionally, two sows in other breeding groups had aborted. The females would go off feed the day of the abortion, but otherwise appeared healthy before and after they aborted. The females were fed a non-medicated ration. All females had been vaccinated with Farrowsure to protect them against leptospirosis, porcine parvovirus, and erysipelas. Bruce performs all the vaccinations himself according to farm protocol: Each gilt received 5 mLs of Farrowsure by injection in the neck muscle at 5 and 2 weeks prior to breeding. Sows received 5 mLs of Farrowsure by injection in the neck muscle at weaning.

Bruce also mentioned that baby pigs in the farrowing house have started scouring. Scours was a common problem in the past but had been controlled for the last few months through *E. coli* vaccination with Litterguard LT, 5 and 2 weeks before farrowing.

EFFECTIVE ANTIBIOTIC TREATMENT

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Antibiotics are a powerful tool in the fight against many diseases of livestock. They are the main tool in the treatment of most bacterial infections in swine. During disease outbreaks they not only are useful in treatment of those that are sick, but also in reducing the impact of, or even preventing, disease in other pigs in the group that are at high risk of infection. When confronted with a disease break, where bacteria play a role, there are several questions a producer and/or his veterinarian asks:

- What's the nature of the disease and what systems are involved (based on clinical signs)?
- What type of antibiotic to use – usually based on what type of bacterial infection (best assessed by laboratory analysis)?
- What way should the medication be administered – injectable, water or feed?
- How long to treat?
- What would be the cost of treatment compared to the potential loss?
- What dose of product to use based on animal weight and label instructions (unless an off-label dose is prescribed by your veterinarian)?

Even with all bases covered, most producers have seen treatment failures. Why do these occur? Often the reasons are not clearly evident and are subject to speculation but include:

- The animal treatment started too late relative to the aggressiveness of the infection.
- Some of the bacteria causing the problem were resistant to the antibiotic used.
- The wrong type of antibiotic was used for the type of bacteria responsible or the body system affected.
- The antibiotic was right but the dose was inadequate (either a miscalculation of the weight of the animal(s) treated, technical errors or failure of the administration equipment (inaccurate water medicators) or the treatment was not given for a sufficient number of days.
- The injections were made into the fat layer rather than muscle (inappropriate technique), or, in the case of oral products, intake was less than anticipated.
- The wrong delivery form of the drug was used (for example an oral product was used where an injectable product would have delivered a higher medication level to internal organs).
- The level of active ingredient in the product is reduced perhaps due to inappropriate storage.
- Bacteria did not cause the disease in the first place as in the case of viral infections.
- Concurrent infections or environmental conditions are exacerbating the disease.
- The animal's immune system was weakened - even with the antibiotic, they cannot control the infection.

In this seminar, I will solicit the groups' experiences with treatment failure. To lead this discussion, I would like to highlight a specific case of an acute diarrhea break in gilts and sows in a 3000 sow farrow-to-wean herd in southern Manitoba. This herd was a very high performing herd reproductively. The average parity was 3.9. It was regarded as a stable herd in disease and productivity status.

The problem began when the breeding/gestation manager of the barn found two mature sows dead in one section of the gestation area during the morning checks. They were both pale and one had some brownish-black staining of the skin in the area below the anus. The afternoon check revealed another sow dead. The next morning three more dead sows were found with similar signs and sixteen sows were not eating. Five of these had a reddish-brown pasty diarrhea. The manager submitted the dead sows to the local diagnostic laboratory and treated the animals off-feed with injectable oxytetracycline – 300 mg per 100 pounds body weight intramuscularly. This treatment was continued over three days for all sows that survived that long. Of those sixteen sows, ten died within 48 hours.

The preliminary diagnosis from the diagnostic laboratory was that the sows had died from proliferative hemorrhagic enteropathy (PHE). PHE is caused by a microorganism called *Lawsonia intracellularis*. These sows were afflicted by the acute or sudden form of the disease that can also cause a disease called ileitis in grower pigs. In ileitis, the effects are more prolonged (chronic) and results in pigs that do not grow well and fall behind the rest of the group. The organism attacks the cells that line the small and large intestine causing proliferation of the cells. Ultimately this disrupts the integrity of the inner surface of the intestine leading to poor absorption of nutrients from the digestive tract in the chronic case, to sloughing and bleeding of the intestinal lining in the acute case.

With this information, the barn manager elected to put tylosin phoshate (Tylan® Elanco Animal Health) into the feed at the label dose of 110 ppm for all animals in the breeding gestation areas. Tylosin is an effective treatment for *Lawsonia intracellularis* infections. The farm continued to treat sows with oxytetracycline injectable. The in-feed treatments were maintained over the next sixteen days. But in spite of this, the numbers of animals sick or dead from *Lawsonia intracellularis* infection increased rapidly over the first ten days of the outbreak. The numbers affected then stabilized and started to decline until no new cases were seen at eighteen days after the start of the problem. The final tally was two hundred eighty sows (all parities were similarly represented) that were clinically ill and treated by injection and eighty-four dead (most of these would have been injected at least once). Also eight percent of the affected sows that were pregnant aborted their litters.

The barn manager thought that the treatments provided some help to keep affected sows alive. But why did sows become ill and die days to weeks after the start of a preventative in-feed medication program with a product that is regarded as very effective against *Lawsonia intracellularis* infections? Was it a case of antibiotic resistance, appropriate medication or dose, disease dynamics or other possible causes as listed above?

We may never know exactly. A key question pertaining to this case: Did the animals in this case consume an effective amount of medicated feed? The poorer than expected response to therapy may be related to the ineffective delivery of the proper dose of medication to the site of bacterial activity. Doses given on the label of most oral products indicate the level of medication to mix into a certain amount of water or feed. The underlying assumption for these label directions is that the targeted animals will consume enough feed or water containing the medication to hit a target dose based on the animal's body weight. In this seminar, we'll explore and discuss this and other possible causes of the treatment failure.

CASE STUDY IN SWINE REPRODUCTION

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THE PROBLEM

The telephone call came the end of October. “I’ve got really low conception rates: lots of the pigs I bred in late September are coming back into heat. I sort of expect this kind of thing in August – but not now! What’s going on and what can I do?”

My response is to assume that my immediate first guess might be wrong, and therefore find out as much as I can about the situation before making any conclusions. So I ask many questions: these are given below with a summary of the answers and the reasons the questions are important.

QUESTIONS

1. Are you on a record keeping system?
2. How many pigs do you breed per week?
3. What are your conception rates now?
4. What were your conception rates in late September/early October? In April? Overall for last year?

    Reasons: These questions confirmed that there really *was* a problem. Valid computer records detailed the breeding of over 25 females per week. More than 22% of females bred in mid-late September and early October had come back into heat, compared to 10% overall last year and 8% in April: breeding in early-mid September had about 15% returns, but varied week to week. We explored this variability a bit further, in addition to continuing on with the usual run of questions.

QUESTIONS

5. What were your weekly conception rates through August and September?
6. What were your rates for August of last year?
7. What breeding system do you use, natural or AI?
8. Is the problem in gilts or sows or both?
9. What breeds do you have? Purebreds? Crossbreds? Are they all affected?

    Reasons: These answers were most informative. The producer uses a mixture of AI and natural breeding (hand mating, all breedings observed), with AI for his purebred lines and sometimes for production of replacement crossbred females, and natural breeding for his three-way cross market pigs. Conception rates for breedings done in the second and third weeks of August were low (giving 18% returns) and very low rates for breedings in the fourth week of August (25% returns). These involved all females regardless of age or breed, although AI in purebreds was perhaps a wee bit better. He noted that August was hot, with an extreme heat wave through the entire fourth week of August. Breedings done in early to mid September had generally improving conception rates, but these then started to drop again (temperatures were definitely cooling), which was when he called. Interestingly, this later decline in breeding rates was only in his market pigs, not his purebreds. And finally, last year's August breedings also had low pregnancy rates: "That's why I said I expect this in August! It's this new crash after they'd started to climb again that worries me."

QUESTIONS

10. Have you changed anything since April or since last year?
    a) Staff doing the reproductive work
    b) Heat detection method? Time from observed in heat to first breeding?
    c) Breeding method
    d) Age or breed of female or male (boars at home, or providing AI semen)
    e) Semen supplier for AI, semen storage on farm
    f) Feed or feed supplier
    g) Housing
    h) Weaning
    i) Gilt / sow replacement
    j) Health status (that is, any major disease issues)
    k) Health procedures
    l) Record keeping system

Reason: Staff, particularly those who check heat and breed the females, are crucially important. Despite some staff turnover and holidays, the new people were experienced, were familiar with the farm's methods, and appeared to be performing well – although the record keeping system didn't specifically allow checking for who did what breedings. Heat checking was done twice a day using a boar, morning (after feeding) and late afternoon, with the only change being that in the hottest part of the summer they checked for heat the very first thing in the morning when it was coolest. They bred sows twice, and gilts approximately every 12 hours until they would no longer stand. There was a feeling that fewer females than usual stood for a second breeding through August, but no records were available. Age, breed and semen supplier were unchanged.

Feed is prepared on site, using home-grown or contracted corn and soy. New crop started to be available through September. Housing didn't change, although ventilation fans were going full speed through most of August, with some "usual problems": these 'usual problems' included a fan motor burning out on the hottest night, periodic poor functioning due to power fluctuations and brownouts, etc. There were no major changes in disease status or standard health measures, which obviously could have caused reproductive problems. The record-keeping system was unchanged. It of course won't change any situation, but can affect detection and visibility of existing situations.

With no other obvious causes, August seemed to hold the key. For each boar, the number of breedings and conception rate in mid-late September was compared to its records for June, July and August breedings. Three boars, each used excessively, had very poor pregnancy rates in the late September breedings. Fresh semen I examined from several of his boars and from his AI supplier was of excellent quality; the semen from only one of the three problem boars had low sperm concentrations and many immature sperm.

THE CONCLUSION

The poor pregnancy rates in the early August breedings likely resulted from the inherently lower summer fertility in pigs (particularly females), made worse at month end by heat stress. Semen was only a minor factor then. Pregnancy rates improved in early September breedings as the females recovered from the heat stress and were bred by sperm whose production was basically complete prior to the heat wave. The heat wave did devastate sperm that were being produced at that time, so once the last good sperm were used up, there were not enough good sperm in the on-farm boars to get the market pigs pregnant. The AI semen was quality checked before being sold, so was fine. The semen quality I observed meant 2 of the 3 problem boars had recovered.

THE SOLUTION

Sperm production takes 6 weeks in pigs, so sperm production should be returning to normal, as seen in two boars. Watching the individual boars' records closely and not overusing any boar promotes steady, good pregnancy rates. Supplement boars with AI using pooled semen or cross-bred semen on market gilts when extra boar power is needed, particularly during and after heat waves. Breed more females to compensate for the natural decline in fertility in late summer.