Proceedings

of the

4th LONDON SWINE CONFERENCE

Building Blocks for the Future

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Building Blocks for the Future

Edited by
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CHAIR'S MESSAGE

Welcome to this year's London Swine Conference – **"Building Blocks for the Future"**.

Over the last ten years the two consistent features of the pork industry has been change and challenges. Although it is not easy, people in our industry continue to take on the challenges and implement change to create successful opportunities. This does not happen over night, but by tackling the challenges head-on, a more efficient and innovative industry is emerging.

To drive this process, the London Swine Conference provides a platform to accelerate the implementation of new technologies in commercial pork production in Ontario. During the two-day conference, participants will have the opportunity to exchange and discuss ideas with internationally renowned speakers and innovative industry leaders. Presentations, panel discussions, breakout sessions, and networking provide everyone the opportunity to learn.

This year's theme, **"Building Blocks for the Future"**, centers on the nursery and grower-finisher segments of the industry. Health, housing, marketing, nutrition, waste management, economics, and decision making are the broad range of topics that our speakers are focusing on.

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

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

Enjoy the Conference!

John Bancroft
Chair, Steering Committee
2004 London Swine Conference

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SETTING THE STAGE: PRODUCING PORK IN A CHANGING ENVIRONMENT

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INTRODUCTION

It has been said that the only thing constant in life is that things will always change. Our industry offers a prime example. I grew up on a prairie farm that grew crops, milked cows, cattle for beef, chickens and of course hogs.

As I remember, all the kids going to our country school had farms similar to ours. Farms changed over time. Farms became more and more specialized, mostly straight grain farms.

A CHANGING BUSINESS

I started farming in 1975, not growing crops but with 20 acres and a new hog barn. My father always said we raised hogs to lift the mortgage. I always wondered why we bothered with the rest. Over the years, building barns and changing how things were done became the norm. The speed of change has accelerated to the point it has became breath-taking. The 900 or so hogs that my early operation took 12 months to raise are now produced in every 12 hours at Big Sky Farms. Smithfield Foods does it in 36 minutes. Genetics, health, nutrition, food safety, welfare, environment and economics have all changed dramatically.

THE CHANGING MARKETPLACE

In earlier times, food was raised close to the consumer. Wall Street in New York got its name from the wall built to keeps hogs out of the city. Many hogs were slaughtered on the farm or by butcher shops in towns. The big towns had bigger butcher facilities. Regions were generally self-sufficient. Later, improvements in transportation allowed food to move. Perishable foods like meat waited for the age of portable refrigeration. Economics of business lead to fewer and larger systems to supply consumers their food.

THE FACTORY

The family abattoir and corner grocery store has been replaced by big companies supplying millions of consumers. Big companies do things on a large scale. Factories make large quantities of few things. Factories focus on design, uniformity and least cost. Today, many hog producers are labeled as operating factory farms. Consumers use a multitude of products made in factories, yet seem to desire their food grown on the idyllic family farm. Niche markets have arisen that are willing to pay a higher price for such products. However, mainstream food supply continues to strive for lower costs, uniformity and safety. I cannot deny it. Big Sky Farms operations are hog factories. In our factories, we have well designed pig quarters, great nutrition and professional animal care. We produce large volumes of uniform hogs to provide low cost, safe and dependable pork for national and international markets.

DIVERGING MARKETS

As an industry, we should not discourage producers from identifying and filling niche markets. If a group of consumers want ‘free range’, ‘Berkshire’, ‘natural’ or ‘organic’ pork, economics should dictate the supply. Production, processing and marketing these niche products needs to be tailored to the market. However, we need to recognize that mainstream hog production must fill the needs of the mainstream market. About 50% of hogs born in Canada will be consumed outside of Canada. Our mainstream production must therefore compete in a global marketplace. Global consumers have the luxury of accessing supplies based on price, food safety, traceability, country health status, politics, animal care, environmental factors or any other criteria they deem worthy at any point in time. Canada cannot and should not assume we will have a long term favored status in any market. Just ask our beef producers about the American market today.

DOMESTIC TRENDS

Far be it for me to know what the consumer will desire tomorrow. Consumers today are placing a high discount on un-safe food. Dioxin residues in meat in Europe caused scandals in recent years. We are accused of using drugs, antibiotics and hormones to get our animals to market cheaply with disregard to residues. Testing does show that residues are found on occasion. Animal care is thought to be lacking on intensive operations. Unfortunately, there are examples of bad care. However to suggest that this is only a problem on large operations is very naïve. Some of the worst cases of animal abuse occur on hobby farms. Environment lapses have been blamed on intensive livestock operations. North Carolina and The Netherlands are often cited as examples. The Walkerton E. coli sickness is mentioned in Canada. This was a case of many errors, none to do with our definition of an intensive livestock operation. Consumers will demand minimum standards for food production or many will not buy our product.

Consumers are also buying their food from fewer and larger markets. Most purchases are based on convenience and price. Wal-Mart, Superstore and other retailers duke it out for the consumer. These guys demand what their consumer ants, in quality, quantity and lowest price possible. Consumer power has been concentrated in fewer and more powerful retailers hands.

FOREIGN TRENDS

Export markets have trends tailored to their culture. Europe has restrictions that are based on slaughter plant certifications, antibiotic/drug/hormone use and animal welfare. The bottom line is that they don't want foreign competition and will use non-tariff barriers to keep us out.

Japan had tariffs to keep domestic prices high for many years. However, when BSE caused scandals, food safety and country of origin labelling became high priorities. Japan now requires country of origin labeling for all meat. USA attempted to enact country of origin labeling for political reasons and it is still a possibility. Traceability will be a pre-requisite in the future. BSE has shown us that the movement of live animals across borders is much more difficult than meat. Meeting the needs of the foreign markets is much more than price and supplies.

THE TIME BOMB

Canadian hog production is now split evenly between domestic and export markets. About 7.8 million pigs moved live into the USA. Of these, about 2.2 million go south as market hogs and 5.6 million feeder pigs. Canada cannot physically feed all our pigs if the USA border closes. Even if we could, we cannot slaughter the finished hogs. What would happen to our market if the USA border closed for any reason? **KA-BOOM!** As an investor with millions tied up in hog barns, this is an un-acceptable risk. Slaughtered hogs can be boxed, frozen and shipped to 100 plus countries. The frozen product can also be put in storage. We must expand our slaughter capacity. **This must be a priority!**

SELLING THE MEAT

If we finish all these pigs in Canada, then slaughter them here, can we sell the meat? The Americans appear to be buying our pigs now and selling the meat. Americans have high volume, double shifted and low cost plants. To compete with Tyson or Smithfield's head to head on price alone may be a problem. But the Danes compete successfully with North America while having a definite cost disadvantage. Their cost of production is about 25% higher than ours. Their total cost of slaughter plant workers with benefits is $40 per hour Canadian. They survive by marketing themselves on quality and uniformity. We need to be comparable to the Danes on quality and comparable to the Americans on cost. If we then make sure the market appreciates what Canadians can deliver, we will flourish.

BRAND CANADA

As the requirements of the marketplace become more sophisticated, producers must meet the challenge. Multinational integrators have tightened their systems by controlling the whole food chain. Producers like the Danes have closed the loop by ownership of processing. They have high standards for the food chain. We in Canada can compete with the Danes as professional food suppliers. Our slaughter plants for export are required to be federally inspected. If federally inspected plants accepted only Canadian Quality Assurance™ qualified hogs, our CQA™ program can be the platform for the Brand Canada. CQA™ already defines the use of medications and documentation. CQA™ could require hogs be feed quality controlled feed. Animal welfare standards can be added to CQA™. Environmental standards can be added to CQA™. Transportation can be added.

WHO PAYS? CAN WE AFFORD THIS?

Canadian producers have billions invested in facilities and stock not to mention the tens of thousands of people that depend on our success. Finding our international market niche will be a definite asset. If we want to compete on price alone, we need to beat the Brazilians and the Poles. Our best bet is to be safe, wholesome and reasonably priced. I believe we can all benefit by making **BRAND CANADA PORK – THE BEST IN THE WORLD!**

HEALTH MANAGEMENT OF THE WEANED PIG

MANAGEMENT TO OPTIMIZE PRODUCTIVITY OF THE WEANED PIG

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ABSTRACT

Management factors to optimize the productivity of the weaned pig include communicating the proper message to barn staff, sanitation and barn preparation practices, healthy pigs of maximum weight and age entering the barn, and feeding management practices. Clearly, these factors are interrelated and important to optimize nursery productivity.

INTRODUCTION

A successful nursery management program depends on many interrelated practices. These include the importance of weaning weight and age for a successful start in the nursery, as well as feeding and environmental management procedures to enable successful performance. Diet formulation and ingredient selection to maximize performance and minimize cost and disease problems also are important factors to optimize nursery productivity.

COMMUNICATE THE MESSAGE

Do the people understand the program? At K-State we work with a wide range of production systems and interact with a wide variety of people including owners, managers, contract growers, owner operators, and frontline employees. Commonly, we encounter nursery programs with below optimum performance. Many times the cause is because of inexperience or communication and cultural barriers of workers who fail to understand desired procedures rather than technical problems such as diet formulation.

Do you have the right personality? The KSU Swine Nutrition group and several producers that we work with have used formal personality profiling to enhance communication and categorize the most effective methods of communication. Usually, we find that if we are having a difficult time with compliance or getting the message across it is not the fault of the audience that we are dealing with but rather a need for communicating the message in a different format.

Is management communicating the proper message or are they communicating a message? An example is communicating the importance of feeder adjustment. The importance of proper feeder adjustment for improving feed efficiency is well known to producers, employees, and professional advisors. However, this is the number one cause of sub optimal feed efficiency we encounter on farms time and time again. When discussing feeder adjustment with personnel in the barns, few disagree that adjustment is important, however, there is much confusion as to how much feed should be in the pan for optimal feed efficiency. Usually, we find the message being communicated by different service managers is different. We have found using pictures of a properly adjusted feeder has been a very effective communication tool. Therefore, each service manager is working from the same standard. Additionally, several productions systems have placed the pictures of optimally adjusted feeders in every barn of pigs.

START OUT WITH HEALTHY PIGS

Without a doubt the swine industry has restructured dramatically in the last decade to harness the health benefits of multi site pig production. While extremely successful at minimizing the impact of chronic disease, the impact of viral agents such as porcine reproductive and respiratory virus, swine influenza, and circovirus have increased. Field reports seem to indicate dramatically enhanced nursery growth performance when PRRSV elimination programs have been successful.

Therefore, it is imperative to deal with health challenges immediately with proper diagnostics and an appropriate therapeutic plan. As the veterinary profession is under increased scrutiny, we must continue to make informed therapeutic decisions and ensure that safe and effective treatment protocols are being used.

PERFORM PROPER CLEANING, DISINFECTING, AND DRYING

It has been well documented that animal performance is increased in “clean vs. dirty” environments and cleanliness is probably responsible for a large percentage of the growth performance benefits from all-in-all-out production. Also, since the young pig is more susceptible to infections from enteric organisms this is especially critical for nursery facilities. In general, organisms are protected against agents of disinfection by organic materials such as pus, serum, or feces. Fortunately, most swine pathogens only survive for a brief amount of time outside the host in the absence of organic materials or moisture. Up to 99% of bacteria can be removed by cleaning alone under experimental conditions. However, the relative importance of the stages of sanitation include: 1) 90% removal by removing all visible organic matter, 2) 6 to 7% killed by disinfectants, and 3) 1 to 2% killed by fumigation (Morgan-Jones, 1987).

Recent reports indicate that environmental contamination is an important contributor of Salmonella infection (Nietfeld et al., 1998; Davies et al., 1999). From one study, 27% (7/26) of drag samples obtained from a fully slatted finishing floor just prior to placement of pigs were found to be positive for salmonella. Anecdotal observations from our group indicate that there is a seasonal nature to enteric problems in nurseries during the latter winter and early spring period. We have observed that during this time period, due to environmental conditions, nursery spaces take longer time periods to dry and pigs are commonly placed in nurseries with moist surfaces and humid environments. Other observations indicate that feeding mat sanitation is also an important factor. If using feeding mats, we advocate they only be used for the shortest time period (3 to 5 d) after weaning.

SET THE BARN UP PROPERLY BEFORE THE PIGS ARRIVE

In addition to sanitation, before arrival procedures include setting ventilation controls to allow for the room to dry and warm up. If used, mats and supplemental heat sources should be in place and functioning. All waterers should be functioning and adjusted to the proper height. Waterers should be set at shoulder height for the smaller pigs in the pen. Regardless of whether the first diet after weaning is bagged or bulk, the feed gate in all feeders should be closed before the first pellets are placed in them. The feed gate then is opened so that a small amount of feed is visible in the feed pan. Placing pelleted feed into empty feeders with the gate open will result in large amounts of feed wastage.

During the first 36 hours after weaning, pigs need to find the water and feed. During this time period height adjustment of waterers should be rechecked to ensure proper access to water for pigs, feed should be always available in the feeder, and small amounts of feed should be placed on the mats to encourage feeding behavior. Also, during this period the environmental temperature and zone heat are adjusted to ensure that the pigs are comfortable. Standard environmental temperature recommendations are difficult to generalize due to differences in effective temperature due to flooring materials, heating sources, and drafts. Therefore, the objective during the immediate period is to make minor environmental adjustments and let the pigs rest and acclimate after weaning.

The transition period immediately after weaning is a critical time in nursery management. Water intake is crucial in the newly weaned pig. Because of the low body weight in proportion to metabolic rate, dehydration occurs easily in young pigs. The unguarded center-flow water nipple has worked well in the SEW nurseries at Kansas State University to facilitate drinking and prevent dehydration. In addition, it is important to ensure that the water pressure is below 20 psi, so that pigs can easily operate the water nipples. Many producers block or tie the nipples open for the first 24 hours, so that the newly weaned pigs rapidly find the waterer. Cup waterers have been used successfully in other nurseries. A simple rule of thumb to use for height adjustment is shoulder high for the smallest pigs in the pen.

If all of the proper preparatory procedures are performed, the pigs can be left to rest for approximately 36 hours after weaning. Pigs should be observed to ensure that they have found the water source and are beginning to develop feeding behavior.

COST EFFECTIVE DIET FORMULATION AND HIGH INGREDIENT QUALITY

While diet formulation and ingredient selection are critical factors for successful implementation of nursery programs this section will only briefly outline some commonly encountered problems. A general outline for diet formulation and feed budgeting in the nursery are provided in tables 1 and 2. For a discussion of the specific nutrient requirements as well as recommended dietary formulation for nursery pigs, please refer to Tokach et al., (1997), Nelssen et al., (1999), or Tokach et al., (2003). The major principle of nursery diet formulation is to transition pigs to a grain soybean meal-based diet as rapidly as possible without sacrificing growth performance. Feed intake is critical for the maintenance of thermoregulatory capabilities. The relative rate of body heat loss is greater for lighter weight pigs than heavier weight pigs. Rarely is feed intake maintained at a sufficient amount to sustain before weaning growth rates and maintenance energy requirements. Thus, maximizing feed intake after weaning reduces stress and increases growth rate by decreasing the mobilization of lipid stores to provide energy for protein deposition (Whittemore et al., 1978). As feed intake increases after weaning, a lower effective environmental temperature is needed to maximize pig growth performance. Therefore, a rapid increase in feed intake is a high priority when weaning lightweight pigs because of their relatively larger amount of heat loss compared to heavier pigs.

Table 1. Recommended sequences and composition of nursery nutritional programs.

SEW Diet for pigs weighing less than 5 kg	Transition Diet for pigs weighing 5 to 7 kg
Grain-based	Grain-soybean meal-based
1.6 to 1.7% Lysine	1.5 to 1.6% Lysine
0.44 to 0.47% Methionine	0.38 to 0.43 Methionine
18 to 25% Lactose equivalent	15 to 20% Lactose equivalent
5 to 7% Spray-dried animal plasma	2 to 3% Spray-dried porcine plasma
10 to 15% Soybean meal	2 to 3% Spray-dried blood meal and
3 to 6% Added fat	(or)
0 to 2% Spray-dried blood meal	Select menhaden fish meal
3 to 7.5% High quality fish meal	3 to 5% Added fat
3,000 ppm Zinc oxide	3,000 ppm Zinc oxide
Pelleted	Pellet or meal form
Phase 2 for pigs weighing 7 to 11 kg	Phase 3 for pigs weighing 11 to 25 kg
Grain-soybean meal-based	Grain-soybean meal-based
1.30 to 1.50% Lysine	1.25 to 1.45% Lysine
.36 to .41% Methionine	.34 to .40% Methionine
6 to 8 % Lactose equivalent	No added specialty ingredients
2 to 3% Spray-dried blood meal	0 to 6% Added fat
or 3 to 5% High quality fish meal	0 to 250 ppm Copper sulfate
0 to 3% Added fat	Pellet or meal form
2,000 ppm Zinc oxide	
Pellet or meal form	

Table 2. Example feed budget (amount, kg of each diet that should be fed/pig).

		Weaning Age and Initial Weight		
		14 d	21 d	24 d
Diet	Pig weight, kg	4 kg	5.9 kg	6.8 kg
SEW	< 5 kg	0.9	0.4	-
Transition	5 to 7 kg	2.3	0.9	0.9
Phase 2	7 to 11 kg	6	6	5
Phase 3	11 to 25 kg	23	23	23

Ingredient quality is imperative for the nursery diet, such as using edible grade dried whey, spray-dried blood meals, and high quality fish meal like select menhaden. We frequently encounter diet formulation errors such as incorrect pharmacologic zinc concentration and inadvertent substitution of ingredient sources (Tokach et. al, 2000). Therefore, we recommend scrutinizing mill formulations closely and making periodic feed mill audits to ensure that desired ingredients are being used. Minimize manual feed handling, size deliveries and bins to maximize efficiency of feed delivery and feed budgeting. Many producers eliminate as much hand feeding as possible. They concentrate their time and effort on skills that are not easily automated, such as treating sick pigs, observing eating behavior, and making environmental adjustments. Labor needs and attention to management in the early period after weaning are critical. This is the most important time to prevent starve out pigs and eliminate problems with habits such as navel and flank sucking.

Slight alterations in the appropriate amount fed can be made based on a minimum feed mill order, size of the delivery compartments of trucks, and location of the nursery on delivery routes from the feed mill. Feed processing and delivery charges account for approximately $.01 per lb. of gain or $.40 per pig in the nursery phase. Therefore, synchronization of optimum feed processing and delivery in nursery feeding programs represents a significant opportunity to increase efficiency and decrease cost.

Overfeeding of the first diets after weaning is a common cause of excessive feed cost in the nursery phase. However, based on the relatively wide range of weight distribution in nurseries with pigs that have widely varying nutrient requirements, astute nursery managers modify the amounts of segregated early weaning (SEW) and transition diets that are fed by pen within a nursery.

The phase 3 diet is the lowest cost diet in the SEW nursery-feeding program. However, because consumption of the phase 3 diet is the greatest, it usually accounts for 50% of the total feed cost from weaning to 23 kg. Thus, cost of this diet is critical to minimize total feed cost while maximizing performance in the nursery. Specialty ingredients, such as spray-dried blood meal, fishmeal or dried whey, are cost prohibitive, because research has failed to indicate improved growth performance from feeding such ingredients in phase 3 (Kats et. al., 1994).

MAXIMIZE WEANING WEIGHT AND AGE

A critical area that impacts nursery feeding and management is age at weaning. It is generally recognized that implementation of earlier weaning ages results in a greater output of pigs per year. The decreased subsequent reproductive performance is overcome by an increase in litters per sow per year. However, populations of weaned pigs within production operations are commonly assigned an equal value, regardless of weaning age or weight. Although there are typically individual pig quality criterion or discount programs, weaned pigs meeting the minimum standards are valued equally. Additionally, in multi-site production the sow farm is evaluated as a separate financial entity or cost center. Therefore, in these production systems, increasing pig numbers regardless of age or weight are strong drivers of sow herd financial performance. These drivers produce strong motivation for production managers to decrease weaning age. However, pigs weaned at heavier weights and older ages are simply easier to manage in the nursery and have lower risk of developing enteric disease (Cranwell et. al., 1995; Madec et. al., 1998). Other data indicate that pigs with lighter weight at weaning are at a higher risk of death (Deen et. al., 1998).

In a recent experiment, we characterized the importance of weaning age on growth performance in the first 28 d after weaning (Tokach et. al., 2003). We grouped pigs by age (12 to 15 d, 16 to 18 d, and 19 to 21 d old) and weight (light or heavy) within each age category (Table 3). We found a weaning age by growth performance interaction ($P < .07$). Note that the difference in average weight between the heavy and lightweight categories was approximately 1 kg (Figure 1). Thus, the heavy 12 to 15-d and the light 16 to 18-d old categories averaged similar weights at weaning. The heavy 16 to 18-d and light 19 to 21-d old categories also averaged similar weights at weaning.

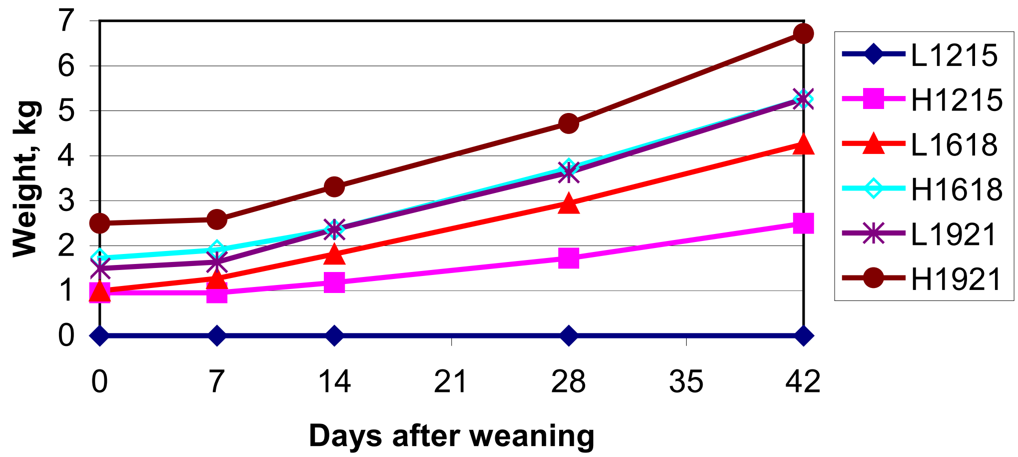
Table 3. Influence of weaning age (d) and weaning weight (lb.) on nursery performance.

Age:	12 to 15		16 to 18		19 to 21			P Value		
Item Wt:	Light	Heavy	Light	Heavy	Light	Heavy	SEM	Weight	Age	Wt x Age
d 0 to 28										
ADG, g	213	241	286	286	309	295	5	0.05	0.01	0.07
ADFI, g	309	331	381	395	395	409	9	0.04	0.01	0.79
Feed/gain	1.46	1.38	1.35	1.39	1.37	1.39	0.02	0.83	0.10	0.04

Each number is the mean of 12 pens (21 pigs/pen) and pigs averaged 5.3 kg at weaning.

The youngest pigs at weaning gained the least from day 0 to 42 after weaning. The data clearly show that weaning weight is important with all ages of pigs; however, the impact of weaning weight was not as important as weaning age. When comparing pigs that were 16 days or older at weaning, the weight differences at weaning were only slightly increased by day 42 after weaning. Weaning weight was also important for pigs weaned at less than 16 days; however, age also becomes a critical factor as pigs with heavier weaning weights within the 12 to 15 d old category were not able to compensate for their young age. The heavy 12 to 15 day old pigs had the same weaning weight as the light 16 to 18 day old pigs; however, they were 2 kg lighter at day 42 after weaning. Weaning weight differences also become magnified with young pigs. Note that while the light 12 to 15 d old pigs were 1 kg lighter at weaning than the light 16 to 18 d old pigs, the difference had magnified to 4 kg by 42 d after weaning.

Figure 1. Influence of weaning weight and age on weight difference between groups.

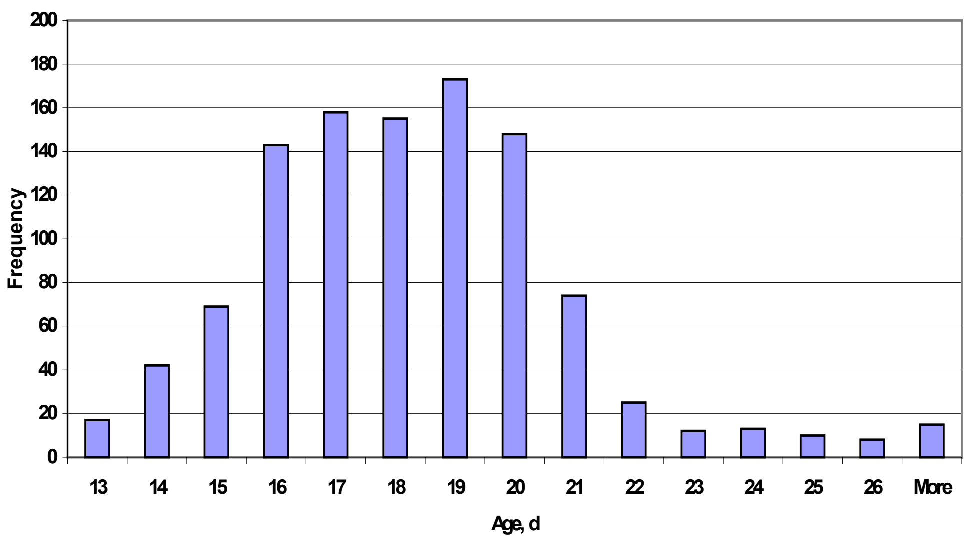


Subsequently, two follow up trials were conducted to determine the effects of weaning age on pig performance in a three-site production system (Main et al., 2004). Trial 2 also evaluated the effects of modifying nursery feed budgets according to weaning age. In trial 1 (2,272 pigs), treatments included weaning litters at 12, 15, 18, or 21 d of age. In trial 2 (3,456 pigs), litters were weaned at 15, 16, 18, 19, 21, or 22 d of age and categorized into three treatments (15.5, 18.5, or 21.5 d of age). In trial 2, pigs in each age group were fed a nursery feed budget classified as more or less complex. Each trial was conducted as a randomized complete block design with four blocks of linked nursery and finishing sites. All wean age treatments were weaned from a 7,300-head sow farm on the same day into the same nursery. Each block remained intact as pigs moved from nursery to finishing site. Increasing weaning age (12, 15, 18, or 21; and 15.5, 18.5, or 21.5 in trials 1 and 2, respectively) improved (linear, $P < 0.001$) ADG (299, 368, 409, 474 ± 7 g/d; 435, 482, 525 ± 13 g/d) and tended to improve (linear, $P < 0.09$) mortality (5.25, 2.82, 2.11, 0.54 ± 0.76%; 2.17, 1.56, 1.30 ± .36%) in the initial 42 d post-weaning. Finishing ADG (722, 728, 736, 768 ± 11 g/d; 783, 790, 805 ± 11 g/d) also improved (linear, $P < 0.01$) with increasing weaning age. Overall, increasing weaning age improved (linear, $P < 0.03$) wean-to-finish ADG (580, 616, 637, 687 ± 8 g/d; 676, 697, 722 ± 6 g/d), mortality rate (9.4, 7.9, 6.8, 3.6 ± 0.95 %; 3.9, 3.4, 2.5 ± 0.5 %), and weight sold per pig weaned (94.1, 100.5, 104.4, 113.1 ± 1.3 kg, 107.6, 111.6, 116.2 ± 1.1 kg). Nursery feed budget did not affect ($P>0.27$) wean-to-finish growth performance. Income over costs ($2.00, 5.11, 7.12, 11.19 ± 0.52/pig; $7.99, 10.04, 12.46 ± 0.46/pig), and cost per hundred lb sold ($39.10, 37.76, 36.96, 35.54 ± 0.21; $36.65, 35.95, 35.15 ± 0.15) improved linearly ($P<0.01$) with increasing weaning age. The improvements in growth and mortality largely occurred in the initial 42 d after weaning, with smaller growth improvements in finishing. These studies indicate that increasing weaning age up to 21.5 d predictably improves grow-finish throughput (i.e. 1.80 ± 0.12 kg sold/(pig weaned • d increase in weaning age) in this three-site production system.

Average age at weaning or lactation length calculated at weaning is based on the date of the last recorded wean event for the sow in most record keeping systems. In many farms where pigs are weaned multiple times per week, the heaviest pigs in a litter are weaned before the remainder of the litter. Thus, the actual average weaning age of the pigs will be lower than that stated on the summary report. We have observed actual weaning age as much as 1 day younger than that reported from average lactation length calculated from the sow wean event. Another common practice, even on farms that have strict policies about movement of pigs among rooms, is to hold back older lightweight pigs to wean them at an older age. This is another phenomena that will not be highlighted in records because the average age at weaning will be calculated based on the wean event of the sow.

Actual data from an experiment by Donovan and Dritz (2000) indicates that, on a farm with a 21 d maximum weaning age policy, 7.8% (83/1,062) of pigs were actually greater than the desired 21 d maximum age (Figure 3) and that 1.4% (15/1,062) were weaned at greater than 26 d of age. Also, note that 12% (128/1,062) of the pigs were weaned at 15 d of age or less. Examination of 1,800 pigs from another production system in which piglets are tattooed with date of birth indicated that 17% were greater than 21 d of age at weaning when the policy of maximum weaning age was 21 days.

Figure 3. Histogram of ages at weaning.



Strict adherence to maximum weaning age has been advocated to minimize transfer of infectious disease. Also, a narrow spread of weaning age has been indicated as desirable for success of isowean programs with a maximum of 20 d of age suggested for the elimination or control of most swine pathogens (Harris, 2000). Our experience indicates that the actual weaning age of groups of pigs is highly variable based on farrowing house management practices. Therefore, even though most nursery pig nutritional programs are based on pig weight, we believe understanding the mean and variation in age are important for successful nursery feeding and management practices.

ASSIST PIGS AND TEACH FEEDING BEHAVIOR

By 36 hours after placement, most pigs will have found water and started to exhibit feeding behavior. However, this is a critical time period to identify pigs that are lacking proper feeding behavior or are becoming dehydrated. This may involve hand feeding a few pellets or using a gruel administered with a syringe. We believe that teaching feeding behavior to a small number of pigs is essential. Developmentally younger pigs weaned at earlier ages do not learn to eat dry diet as quickly as conventionally weaned 21-d-old pigs. The identification of candidate pigs for teaching feeding behavior is a high priority during the first few days after weaning. This is an area of pig management that requires astute observation of pig behavior. Therefore, it is an area on which personnel should concentrate efforts and veterinarians and managers should concentrate training. With proper management of the nursery, the number of pigs requiring extra attention will be limited to 2 to 4%.

The most difficult part of the process involves identifying the small percentage of pigs that are candidates for individual attention. The critical times are approximately 36 to 60 hours after weaning for identifying pigs that are having a difficult time learning proper feeding behavior. For example, for a group weaned on Thursday morning, the critical time period is Friday evening through Sunday morning. Pigs that are eating well will begin to have round abdomens, whereas pigs that have not begun to eat will be gaunt. Although most veterinarians automatically and unconsciously evaluate signs that a pig has not begun to eat, many untrained personnel will have a difficult time identifying the signs. The following mental checklist can be used to inspect pigs from a distance:

- Mental status – alert or depressed
- Body Condition – normal or thin
- Abdominal shape – round or gaunt
- Skin – sleek appearance vs. fuzzy
- Appetite –feeding at the feeder or huddled
- Signs of dehydration – normal or sunken eyes

Depressed mental status, thin body condition, gaunt abdomen, fuzzy appearance, huddling, and sunken eyes are all good indicators that a pig has not been eating or drinking. The appearance of abdominal shape is an especially useful indicator. The abdomen can be palpated for evidence of food intake. Palpating mucous membranes of the mouth or tip of the nose can identify signs of dehydration. Dehydration can be evaluated further by pinching a fold of skin. If the fold remains elevated for more than a few seconds the pig is dehydrated. A good location to do the skin fold test is just behind the front limb. Evidence of urination or defecation also is a reliable sign that pigs are eating and drinking.

Once pigs have been selected for further attention, they should be marked so they can be rechecked until they are feeding on their own at the feeder. One technique that has worked well in several operations is to have a person who can identify the pigs that are not feeding go through the nursery and mark them. This can serve as an excellent training tool.

Two strategies seem to work well for starting pigs on feed. The first strategy is feeding a diet and water gruel multiple times per day to encourage pigs to eat. However, care should be taken so that pigs do not become accustomed to the gruel, leading to difficulty in learning to eat dry feed. Also, the gruel is an excellent bacterial growth medium; therefore, sanitation of the gruel feeding equipment is essential.

The second strategy is to individually teach feeding behavior to the small percentage of pigs that do not learn on their own. This method is based on a technique developed by a Kansas swine producer (Eichman, 1993). After the individual pigs have been identified, a small handful of pellets is wet with water and gently placed in each pig's mouth. Alternatively, if a large number of pigs require attention a small bucket of moistened pellets can be prepared. Some personnel use gruel administered through a 12-cc syringe with the end cut off.

The moist pellets or gruel stick to the tongue of the pig, and it begins to swallow. The next step is to carefully place the pig near the feeder, so it associates the food in its mouth with the feed in the feeder. Setting the pig down gently is important, so pain or stress is not associated with feeding. In fact, people that have mastered the technique will be able to rapidly pick up the pig, resulting in minimal struggle. A good indicator of the operator's technique is that a large proportion of the pigs actually will eat from the person's hand. Hence, this method relies on patience and an understanding of animal behavioral principles.

A small amount of feed such as 20 to 30 g will provide energy to keep the pig from starving. It is critical for small pigs with low body fat reserves to have a ready energy source. Our observations have indicated that in high-health-status, segregated, early-weaned pigs, signs of anorexia, depression, and dullness are more likely to be caused by lack of energy than infectious disease. Thus, giving them feed rather than treating them with antibiotics has saved pigs.

MINIMAL SORTING AND MIXING OF PIGS

It appears that in multi site production systems with a fairly narrow weaning age spread per group that minimal sorting and mixing result in better growth performance. For example in one production system with 12 growers, the growers that do minimal sorting consistently have better growth performance. We have observed as high as 17% of pens left empty at the beginning of the nursery period for sort pens. However, these strategies rarely result in excellent performance. Preliminary evidence from a follow up study to the weaning age by weight study using 16 to 21 d old pigs indicates that there is no advantage to sorting by weight categories upon initial placement into the nursery. While minimizing sorting and mixing of pigs is advocated, lack of individual pig care is not.

ADJUST THE FEEDERS FREQUENTLY

"If your fingers don't ache from cleaning the feed gates, you are not adjusting them properly."

We have observed decreased growth rate as a result of improper feeder adjustment. In an attempt to stimulate feeding behavior, large amounts of the first diet are placed in the feeding pan. Although intention is correct, the outcome is negative. Energy deficiency can result from pigs "sorting" the diet and a buildup of fines in the feeding pan. These fines then lodge in the feed agitator mechanism, making it difficult for new feed to flow from the feeder. This problem is remedied by management of the amount of feed flow in the pan to stimulate development of feeding behavior. Approximately 25 to 50% of the feeding pan should be visible in the first few days after weaning. As the pigs become more accustomed to the location of the feed and adjust feeding behavior, the amount of the feed in the feeding pan should be decreased rapidly to 25% or less coverage. Also, feed agitators need to be tested frequently to ensure that the buildup of fines does not prevent them from working freely.

The data in Table 4 depicts growth performance before and after the institution of an aggressive feeder-management strategy. Contrary to popular belief, reducing the amount of feed present in the pan did not reduce average daily gain. Feed efficiency and daily gain both improved because of decreased wastage and continual access to fresh feed. Our recommendations are to have feed accessible for newly weaned pigs at all times in feeders that are adjusted correctly to teach the proper feeding behavior.

Table 4. Comparison of pig performance before and after institution of an aggressive feeder-management strategy in the first week after weaning.

	Strategy Change	
Item	Before	After
Weaning weight, kg	5.6	5.3
Day 0 to 7 after weaning		
ADG, g	73	100
F/G	2.15	1.27

A total of 3,360 pigs used in analysis. Each number is the mean of 2 groups (Before) or 3 groups (After). Each group consisted of 32 pens each with 21 pigs.

CONCLUSIONS

Optimum nursery management is the sum of many factors such as weaning age, day to day management and critical assessment of management procedures. Recognizing that many of these challenges are interrelated and addressing these areas will lead to successful nursery programs.

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MANAGING DISEASE CHALLENGES IN THE WEANER BARN

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ABSTRACT

A systematic approach is required in order to minimize the effects of disease on production and to minimize the frustration level of the operator. An understanding of the challenge organisms assists greatly in disease management. A well rounded disease intervention plan includes both a review of best management practices in addition to the use of vaccines and other therapeutics.

DISEASE CHALLENGES

Each disease must be identified through an ongoing diagnostic process. The samples can be procured during routine farm visits but more often than not a special trip to the nursery is required to investigate each new disease presentation. Once the diseases are identified they can be prioritized based on their costs to the production system. Disease management plans are then developed both by reviewing the literature and seeking out experts for advice.

"Know the Enemy". The cause of the disease should be explained to staff and owners so that they can have a better understanding of the agent. The more the staff understand the agents strong and weak points the better able they will be to battle the diseases. The use of humour or personification at this stage will help to tell a story or paint a picture about the disease so that the staff can relate to and remember the enemies' weak spots.

The types of organisms within the disease family can also be explained. It is important for the staff to know that not all disease organisms are created equally with respect to the ability to cause disease. From time to time staff will visit with other nursery operators who have the same type of organism but have a more or less virulent strain so that their clinical experience is much different.

The epidemiology of the disease should be explained detailing the age groups most likely to be affected, where the organism lives in the environment, how it is transmitted from pig to pig and what kills it. Is the disease likely to occur only sporadically? Are sites, barns and rooms that are managed with either all in/all out pig flow or continuous flow likely to be affected? If this is a new and emerging disease in the industry then a bit of background to explain why this new disease is causing a problem may help the operator to better understand how to fight the new disease.

“ Every solution creates a new set of problems ”. This is very true in the pig business. The use of isowean technology coupled with earlier weaning ages has coincided with a greater incidence of the “mucosal diseases” including Strep suis, Haemophilus parasuis and Actinobacillus suis. These “Little Bugs” have filled the void left when Atrophic Rhinitis and Swine Dysentery were eliminated.

Diagnosis of the disease is extremely important for the operator to understand. The nursery operator needs to be able to report clinical signs that are apparent in the nursery as this may sometimes be the best guide for initial treatment. The degree of periarticular edema coupled with the incidence of productive cough in the nursery may be the best way to differentiate a flair up of Glasser’s vs. Strep suis. The preliminary diagnosis is most often based on a review of herd history and clinical signs. The gross post mortem findings then help to confirm the suspicions. Having the nursery operator able to use some key criteria will speed up the diagnosis. In the case of Ecoli the classic blue nose, toes and belly with the sunken eyed appearance of dehydration will give some good immediate diagnostic direction. Serology, histological lesions, immunohistochemistry, PCR, culture, and further serotyping will firm up the diagnosis. Don’t perform testing unless you know how you will interpret results.

It is important to let the operator know if the disease agent can express itself in more than one way clinically. The expression of A.suis as “Erysipelas like diamond spots” or sudden death fibrinous pleuropneumonia like App or as a simple septicaemia makes it a bit of a chameleon in the nursery. Similarly the sudden onset “puffing pig ”may not be recognized as a Strep suis pneumonitis.

In putting together a disease control strategy it is important to ascertain which are the primary diseases of the nursery and which are the secondary diseases. Whenever possible the main thrust has to be to control the primary diseases so that the secondary diseases will hopefully take care of themselves. This is sometimes easier said than done. If the primary disease can not be controlled then the next best thing is to control the secondary diseases. An example of this would be the importance of PRRS stability in reducing the incidence of the “ Suis-cide” diseases such as Strep suis and Glasser’s.

“ Remember to do no harm!” When changing a disease control strategy in a nursery with multiple diseases you must examine the proposed changes and try to anticipate if those changes will allow another disease to express itself because you have altered its’ control program.

DISEASE CONTROL CHECKLIST

This disease control checklist is presented as a review of the thought process that should be involved when managing disease in the nursery.

Feed

Energy. Maintain a proper energy to protein balance and use highly digestible sources of energy in the diet for the newly weaned piglets.

Protein. The crude protein and amino acid levels must be adjusted for the age and weight of the pig as well as the average daily feed intake. The inclusion of soybean meal should be limited in the diets for the newly weaned piglets.

Minerals. Review deleterious effects of excesses or deficiencies for the problems at hand.

Vitamins. Ensure adequate daily intake to maintain growth and adequate immune function.

Fibre. This is important in the management of diseases such as post-weaning colibacillosis. Fibre may also be helpful in controlling gastric ulcers that are secondary to empty stomachs associated with disease. Often you can cure the pig with antibiotics only to lose them due to a secondary gastric ulcer.

Acidifiers. Acidifiers can be added to feed to help reduce the stomach and intestinal pH. Organic acidifiers such as citric acid, sorbic acid, fumaric acid, lactic acid and formic acid can be added to the feed. Acid salts such as calcium formate and sodium formate can be used. Inorganic acids such as phosphoric acid, hydrochloric acid and sulphuric acid can be added to the feed. It is becoming very clear that management of the acidity of feed is very useful in terms of controlling diseases of the digestive system such as Salmonella. This type of disease control is exciting because we are finding that disease management techniques such as acidification can be used as an alternate strategy to antimicrobials.

Feed Manufacturing. Heat treatment of feed such as pelleting, expansion or extrusion has been suggested to have an impact on several digestive diseases such as gastric ulcers, Salmonella, and Brachyspira pilisicoli. It has been suggested that in an increasing order of importance pelleting, expansion and extrusion will increase the relative risk of enterobacterial proliferation. Reduced particle size will improve feed efficiency but will increase the risk of gastric ulcer.

Feed Management. It is essential that the newly weaned pig begin consuming feed as soon as possible after weaning. Early detection of pigs that are not eating coupled with “ gruel feeding” will help minimise losses. Feeders must be managed such that molds and mildew that decrease palatability are minimized.

Feed Additives. Prebiotics such as mannin oligosaccharide and probiotics such as lactobacillus can be considered. Most of the information that is available is based on in vitro experimentation. There are a number of probiotics that have now been registered as growth promoters and there is supportive scientific information to back these claims. Other feed additives that control ammonia should be considered when respiratory disease problems are predominant.

Water

Quantity. Well capacity, water flow rates, pressure, drinker number, type and placement should be assessed. Water flow metres can be used to monitor water consumption and determine whether pigs are consuming an adequate amount of water especially within the first few weeks post entry. A water flow rate at the drinker of 0.5 litres per minute at 10 to 20 pounds pressure is recommended for the nursery. An experienced electrician can check for "stray voltage" if no other cause of reduced water consumption can be found.

Quality. Factors such as mineral content, hardness, total dissolved solids, and pH should be considered. The pH of farm water should normally be between 6.5 and 7.5. The pH should be checked and adjusted on a routine basis to within a range of 5.5 to 6.0 especially during the early post weaning period.

Sanitation. Water sources and delivery systems may become contaminated with disease causing organisms such as E.coli. Total coliforms and fecal coliforms should be assessed at least yearly or when problems arise. Water sanitation can be maintained using chlorine or hydrogen peroxide added to the drinking water. The use of chlorine should be monitored by testing for levels of free chlorine at the level of the water nipple. Hydrogen peroxide does not mix well with some medications and may plug the water lines.

Environment

Ventilation Rate. Air exchange rates are important to disease control through removal of contaminants. Increased ventilation rates may increase air speed, which will in turn reduce the effective environmental temperature potentially causing chilling. Increased relative humidity may increase the survival time of bacteria outside of the pig in the room environment. Minimum ventilation rates are established and maintained by measuring the relative humidity (RH) and then adjusting the minimum ventilation rate in order to maintain 65 % RH in the late fall, winter and early spring. Control of RH in the summer is not practical and the room RH is going to be very close to RH outside the barn. In the summer the rapid air exchange rates for temperature control will be most important for pathogen dilution.

Temperature. Chilling due to wide daily temperature fluctuation, as well as rapid small temperature fluctuations contribute significantly to the increased prevalence of disease by increasing stress levels in affected pigs. Chilling has been observed to reduce the peristaltic activity in the gut of the neonatal pig increasing the accumulation of E.coli and toxins in the intestine. Chilling may also be caused by drafts, damp floors, damp pigs or insufficient floor, wall and ceiling insulation. Significant temperature reduction can occur in drafty barns due to drift of air through the barn caused by outside wind pressure. Air drift accounts for much more barn cooling than poor insulation especially in older facilities. Ventilation and temperature controllers should be adjusted so as to ensure that they are set to control temperature fluctuation and daily variability. Inlet placement and control, as well as thermostat cleanliness, sensitivity and placement are important. Targets should be established for both temperature and relative humidity by stage of production and then closely monitored.

Manure Management. The incidence of postweaning scour in general is greater in pigs housed on solid floors with no bedding and in pens where the flooring does not stay clean. This relationship is presumably due to an increase in the pathogen load. Manure levels that approach the slats will allow heavy manure gases to enter the pig's resting area and may have a deleterious effect on feed intake.

Sanitation

" The solution to pollution is dilution". Although most diseases can be seen in brand new facilities that have never previously housed pigs it is still important to ensure that facilities are properly sanitised between crops, so as to reduce the pathogen challenge level on an ongoing basis.

Washing. Improperly cleaned pens that are left contaminated are a source of pathogens in the next group of newly weaned pigs. Rooms should be washed thoroughly with hot water, using a high-pressure sprayer in order to remove all visible signs of organic matter from floors, walls, feeders and drinkers. The use of a detergent while washing will help to remove any organic film that will interfere with proper disinfection. Water should be removed from feeders after washing. Washing should be done as early in the downtime period as possible so as to allow the maximum clean and dry period. This will greatly reduce the population of the pathogens.

Disinfection. A product designed to kill bacteria and viruses on barn surfaces should be used at the appropriate concentration. Equipment used to apply disinfectant must be properly calibrated to deliver an adequate amount of disinfectant without excessive waste. Water lines can also be sanitised between batches of pigs. Special attention should be given to water drinkers or bowls as well as stock tanks used in water medication programs as some pathogens may proliferate in these areas. Thermal fogging of disinfectants can be used to disperse the disinfectant widely throughout the room.

Drying. Leaving a room to completely dry is one of the most effective ways of killing bacteria and viruses.

Concurrent Disease

It is possible that some other concurrent disease may worsen the incidence and severity of the primary disease that you are trying to control.

Internal Parasites. Ensure that the weaners are not exposed to a significant internal parasite burden. An effective breeding herd parasite control program should be in place.

External Parasites. Mange and lice can reduce the effectiveness of the pig's immune system. Sows should be routinely treated for external parasites prior to farrowing. Mange and lice eradication programs should be investigated. These are quite well understood and work in a high percentage of cases when the protocols are diligently followed.

Sort Pen/Hospital Pen/Recovery Pen

"Overstock and Sort". "The sick are the greatest challenge to the healthy!" This refers to the practice of placing 5% to 15% more pigs in the pens as pigs are placed in the nursery. Because only the target numbers for the nursery are placed in total there are a number of empty pens that are left at the beginning of the nursery stage. As non-competitive pigs or sick pigs arise, they are removed from the overstocked pens and placed into a sort pen or hospital/recovery pen. This procedure allows for a non-competitive environment for the least competitive pigs. This practice also allows for removing or streaming the sick pigs from the group. This subsequently reduces the disease challenge to the "at risk" pigs in the pen. The 5% to 15% is adjusted based on genetic variability of growth and expected incidence of disease. If variabilty or disease is less than anticipated then the pens will still need to be thinned down before the end of the batch in order to allow for the growth of the pigs. This strategy is much preferred over sorting between pens where pigs are mixed throughout the barn to " even them up" by size or health.

Stallouts. Thin and dehydrated pigs that are slowly recovering from disease should be collected as a group to enable provision of extra nursing care. Mash feeds, wet feeds or floor feeding are all techniques that can encourage the stallout pig to begin eating again.

Medication

Injectable. Injectable medications should be selected based on the antibiogram of the bacterial isolates. Entire pens including affected and "at risk" pigs may be treated with injectable medication in order to stem the spread of disease.

Water. An appropriate water soluble antimicrobial can be selected based on the antibiogram of the bacterial isolates involved. Electrolyte dispensers for individual pens are available so that more potent electrolyte solutions can be administered to affected pigs. The ability of electrolyte preparations to replace electrolyte losses as well as correct metabolic acidosis will vary from product to product.

Feed. Medications can be selected based on the sensitivity pattern of the isolates. More often than not the medications available in feed will not cover all of the diseases present. In some cases the medication is pulsed at certain stages. As the pig ages and progresses to the next phase of feed another medication can be used that may be more appropriate for the disease that occurs at that stage of production. It is important to recognise that continuous medication in the nursery for control of diseases such as Strep suis may only defer the clinical signs to the grower barn and may inhibit circulation and exposure of organisms to the pig. If exposure to mucosal diseases is to occur it is preferable that it occur while the piglet is still under the influence of maternal protection.

Vaccination

Pre-farrowing vaccines using either commercial or autogenous vaccines can effectively control diseases such as Swine influenza , Haemophilus parasuis and Strep suis that occur in

the nursery. The boosted maternal immunity passively protects the piglets during the nursery period where they are gradually acclimatized to the diseases present in the nursery and build their own active protection. This technique is more cost effective than most medication protocols and is often more effective. It can be more cost-effective than the active immunization of piglets. This technique is especially useful where pigs are mixed in the nursery from multiple sources of variable disease status. These pre-farrowing vaccines programs are very compatible with quality assurance programs.
Oral vaccines using field strains of F4 or F18 positive but non toxin producing E.coli have been reported to be successful in the USA. These E.coli are propagated and fed to pigs via the water on entry to the nursery in order to stimulate intestinal immunity prior to the onset of disease.

Biosecurity

Biosecurity should be reviewed with special attention to breeding stock additions. It is not sufficient to switch sources saying that the health matches based on the presence or absence of a certain type of disease organism. Pigs can only juggle so many diseases at the same time. The last thing you want to do is add a few more isolates of the same type of disease. Certainly it will be important to avoid tracking in disease organisms that can be tough to eliminate from the nursery site. F 18, F4 (K88) E.coli and Salmonella may be almost impossible to remove from a building once the site is exposed.

Genetics

It is clear that there are some genotypes of pigs that do not possess the F4 receptor site on their intestinal epithelial cells and, as such, are these lines of pigs are resistant to E.coli where the F4 attachment is a required virulence factor for the E.coli. Similarly other genotypes have a more responsive immune system and can turn on their immunity to fight disease and just as importantly turn it back off again once they are done fighting the disease at hand. Hybrid vigour is also important in developing disease resistance. On average, crossbred weaners will be less susceptible to respiratory disease than purebred Yorkshire weaners.

Other Management Solutions

Nursery Management Guidelines. The Nursery Management Guideline is an information package that is usually printed on one page. This page is then posted outside the nursery room attached to the wall and usually sealed in a plastic liner. The common information found in this package relates to the typical management practices for the nursery. Details include room identification, water flow rate, starting age and weight of pigs, ending age and weight of pigs, starting and ending room temperatures, the current phase feeding program including medications, instructions for feeder management, water treatments, stocking density, manure management, fly control, rodent control and fan and heater sequencing. The sheets are readily available for access by staff. Once these guidelines are written, there is a clear plan and there is no further argument with respect to the current plan. The guidelines also act as an excellent training tool for new staff and the new employees can review these management guidelines prior to entering the room. Within a short period of time the staff are able to assimilate the information in these guidelines. The plan can always be challenged and improved with mutual agreement.

Organizational Memory. There is only one thing worse than making a mistake and that is making the same mistake again. The development of farm-specific standard operating procedures have allowed for better communication of production management practices to all staff members involved in the process. A periodic review of standard operating procedures raises a number of questions and either re-confirms that current operating procedures are well worth continuing or need to be re-evaluated. When operations become larger and more complicated there is more reliance on written documentation to serve as long term memory. Insanity can be defined as "repeating the same behaviour over and over and expecting a different outcome"

Environmental Testing Equipment. The use of simple environmental testing equipment such as humidity monitors, data loggers, water pH, manure pH, air speed and gas testers have allowed for more detailed understanding of the nursery barn environment. This has greatly helped with disease control as well as the health and attitude of farm staff. This equipment has allowed for more objective ways of measuring environmental quality and can be directly related to the room management guidelines.

Depopulation / Repopulation. When health management protocols are ineffective in controlling the costs of diseases in the nursery then depopulation and repopulation may be the best answer. Of course this will always be easiest when there are only 1 or 2 weeks of production housed at that site. These protocols are well documented based on empirical information and have been extremely successful in terms of returning nurseries to maximum profitability where the sow herd is not the source of the disease. If the sow herd or herds are the source of the disease then depopulation and repopulation will only be a temporary fix at best.

Vice Management. The use of toys in nursery pens can be helpful in avoiding the development of vices such as tail biting and flank nuzzling. Toys are most acceptable to pigs when made of soft, pliable material such as non-steel belted rubber. Keeping the toy suspended off the floor will keep it cleaner and make the toy more attractive for continued use. A slightly frayed end will be more attractive to the pigs. The toy provides an outlet for exploratory behaviour and should be part of your behavioural control program in the nursey. These do not have to be placed in every pen immediately post entry but should be available if vices appear.

CONCLUSIONS

Disease in the weaner barn can be a persistent challenge for producers. Acceptable control and prevention measures should be based on a balanced approach towards minimizing pathogen loads and maximizing immunity. Ultimately the key to disease control is clear goals and objectives, timely review of records, prompt identification of the problem, development of the action plan and proper communication to the team allowing for implementation and adjustment of the plan.

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HANDLING GROWER-FINISHER PIGS

HOUSING DECISIONS FOR THE GROWING PIG

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ABSTRACT

Housing decisions for the growing pig involve more than the typical decisions of full versus partial slats and curtain sided versus mechanically ventilated. Decisions on feeder and drinker design impact both the capital cost of facilities and pig performance once the facilities are constructed. There is renewed interest in large group pens (over 100 pigs per pen) and the impact of management decisions on the effects of various space allocations in the nursery and grow-finish. Large pen sizes along with modifications to space allocation are typical for many wean-to-finish facilities. In both wean-to-finish and conventional systems, previous recommendations to sort by size at placement are being challenged by new data which suggests that variation within a pen of pigs is more beneficial to overall performance of a population of pigs than sorting by size at placement. Management of variation in growth by removal of smaller pigs and placement of these pigs with like size pigs has also been demonstrated to have no effect on overall performance of a population of growing pigs.

INTRODUCTION

To understand the great strides that have been made in grow-finish swine production, one only has to look at the differences in performance at a University of Nebraska swine research center from 1982 and 2002 as presented in Table 1. For both 1982 and 2001, pigs were reared in the same partially slatted confinement facility and fed corn-soybean meal diets in meal form. In 1982, pigs were given 0.83 m^2/pig and three feeder holes per 10 pigs, while in 2001, they were given 0.69 m^2/pig and two feeder holes per 12 pigs.

Table 1. Improvements in pig performance at a University of Nebraska swine research facility.

Item	1982[a]	2001[b]
Initial wt, kg	22.3	28.1
Final wt, kg	93.6	118.2
Daily gain, kg	0.680	0.886
Daily feed, kg	2.27	2.40
Feed:gain	3.34	2.70

[a]Brumm et al, 1982; [b]University of Nebraska Experiment 01306, unpublished

There can be many reasons cited for the vast improvement noted, but several that must be considered include genetics, health, nutrition and feeder design. To separate out the impact of feeder design from all of the other contributing factors, Table 2 was prepared comparing recent performance in the same partially slatted research facility before and after feeder replacement. The improvement in feed conversion efficiency is striking, even when corrected for the differences in sex (barrow vs. gilt) and feed form (meal vs. pellet).

As a consequence of data such as this, producers and their advisors are paying much more attention to design details when purchasing feeders and locating them in the pig's environment.

Table 2. Impact of feeder replacement on pig performance.

Item	Old feeder[a]	New feeder[b]
Initial wt, kg	30.7	36.1
Final wt, kg	95.5	98.6
Daily gain, kg	0.927	0.882
Daily feed, kg	2.51	1.83
Feed:gain	2.72	2.09
Sex	Barrow	Gilt

[a]Brumm, 2002; [b]University of Nebraska Experiment 01305, unpublished

NUMBER OF FEEDING SPACES

Traditionally, advisors to the swine industry have recommended one feeding space per four pigs for the growing pig and one feeding space for four or five pigs for the finishing pig (MWPS, 1991). However, this recommendation makes no mention as to the dimensions of the space, the location of the space within the animals environment, or other factors that influence the growing pigs interaction with the feed delivery device. Australian guidelines are somewhat more specific by recommending one space for four growing pigs with the space recommended to be 250 mm in length (Farrin, 1990). The European recommendation is one space per four pigs with the space averaging 59 mm/pig for 50-kg pigs and 74 mm/pig for 100-kg pigs (English et. al., 1988).

Research on feeder space allocations is surprisingly limited. Wahlstrom and Seerley (1960) concluded that one feeder space per six pigs within the weight range for 30 to 91 kg was probably adequate. Using 12 pigs per pen, Wahlstrom and Libal (1977) concluded there was no difference in performance when three, four, or six pigs were allotted for each available feeder space when wooden feeders were used as the feed delivery device for pigs from 28 to 70 kg.

McGlone et. al. (1993) provided one, two, or three feeder spaces for 20 pigs per pen from 61 to 104 kg live weight. Using a meal diet, they concluded that the feeder space requirement is one space per ten pigs. Bates et. al. (1993) in a study at a commercial swine finishing unit, also concluded that growing-finishing pigs can be stocked at a rate of ten pigs per feeder hole.

Morrow and Walker (1994) recommended that two, single-space feeders be used in pens of 20 finishing pigs when meal diets are available ad libitum. They also recommended that the feeders be sited some distance apart (> 2 m), not side by side when pigs are provided 0.60 m″ per pig pen space from 37 to 91 kg live weight. Growing pigs in this study showed a clear feeder preference, with a higher proportion of feed consumed from the feeder nearest the service passage.

QUALITY OF FEEDING SPACES

Although many feeders have some type of feeder space division, they may not accurately reflect the true space requirements. Baxter (1991) suggested that the minimum width of a feeding space should be the shoulder width of the pig, plus 10% to accommodate pig variability and movement. The shoulder width of a pig, in centimeters, is approximately 6.1 * $BW^{0.33}$, with body weight expressed in kilograms (Petherick, 1983). Thus, the width of feeder spaces for 5-, 25-, 50-, and 120-kg pigs would be 11.1, 19.8, 24.8, and 32.8 cm, respectively.

Baxter (1991) also examined the preference of pigs to eat at different heights. Although pigs prefer to eat from a surface at or slightly above floor level, they can eat from levels as high as their shoulders. Some feeders may have an elevated feeding surface or feed access lever, which could limit feeding if these exceed shoulder height. Elevated feeding surfaces usually require pigs to stand at an angle to the feeder and rotate their heads when eating (Gonyou and Lou, 1998).

The depth of the feeder, from the lip at the front of the feeder to the feed access point at the back, determines the extent to which pigs will step into the feed bowl or trough while eating. When feeder depth was only 20 cm, approximately 50% of 20 kg pigs would step into the feeder while eating. For 95-kg pigs, none would step in at feeder depths of 20 cm, < 20% at a depth of 30 cm, and all of the pigs would when the depth was 40 cm (Gonyou and Lou, 1998). However, large pigs (95 kg) have difficulty eating from an area closer than 20 cm from the front of the feeder.

A compromise in feeder depth is needed when feeders are used over a wide range of pig body weights. Gonyou and Lou (1998) suggest that feeder depths for growing-finishing pigs should be 20 to 30 cm.

All of the design concepts discussed above assume that the pig is standing at right angles to the feeder. However, when pigs are allowed to eat feed placed on the floor along a wall, they stand at an angle of approximately 30^{o} from the vertical surface (Gonyou and Lou, 1998). Such a position may facilitate apprehension of the feed. It may be advisable to consider designs that provide such an angle to the feed access point.

FEEDER DESIGN AND FEED WASTAGE

The movements associated with feed falling onto the floor (feed wastage) were studied by Gonyou and Lou (1998). The most common movements associated with feed wastage were backing away from the feeder, eating while the head was raised, fighting, and stepping into the feeder. Two of these behaviors, fighting and stepping, were more common for smaller pigs that also waste a higher percentage of feed. Fighting was more common among smaller pigs as some of the feeders studied had wider feeder spaces than recommended and two pigs would eat from the same space. As indicated above, when feeders have depths exceeding 20 cm, as required for large pigs, small pigs must step into the feeder while they eat. The compromise required when a wide range of pig sizes is fed from the same feeder results in greater wastage by the smaller pigs.

Table 3 summarizes the critical dimensions for feeder design when the feeders will be used where pigs are given ad libitum feed access.

Table 3. Critical design dimensions for single and multi-spaced grow-finish feeders – ad libitum feed access.

Feeder Specification	Dimensions
Feeder space width	300-360 mm
Feeder lip height	100-125 mm
Feed trough depth	
Lip to delivery mechanism	200-300 mm
Number of pigs per space	
Dry feeder	10
Wet/dry feeder	12

WET/DRY FEEDERS

An alternative to dry feed presentation is to allow pigs to access both water and dry feed from the feeder, with the option to combine them before consumption. This is referred to as a wet/dry feeder. Various methods are used to provide access to feed in these feeders. Some feeders allow access to dry feed on an elevated platform or shelf. The pigs may eat from this shelf or push the feed into the bottom pan of the feeder where it can be combined with water. Another method of accessing dry feed is to press a lever or bar that drops feed into the feeder pan. Water is normally available from a nipple that may be oriented downward or horizontally. A key feature to wet/dry feeders is that there is a separation of the water from the access point of the dry feed. Otherwise the water will "wick" into the feed storage and plug the feeder.

Walker (1990) reported an increase in daily gain and feed intake when water was available at the feeder vs located 3 m distant from the feeder. Patterson (1991) reported no benefit to pig performance for wet/dry feeders.

The decision on wet/dry feeders vs. dry feeders and nipple drinkers located at a distance from the feeder is often based on issues not related to pig performance. Gadd (1988) summarized a series of on-farm experiences and concluded that slurry production was reduced as much as 50% with wet/dry feeders vs dry feeders. Maton and Daelemans (1992) concluded all wet-dry feeders reduce water spillage, resulting in a 20 to 30% reduction in slurry volume. Brumm et. al. (2000), using a two-hole wet-dry feeder for 24 pigs per pen also reported a 30% reduction in slurry volume.

Both Rantanen et. al. (1995) at Kansas State University and Brumm et. al. (2000) at the University of Nebraska report a significant reduction in daily water use for pigs on wet/dry feeders vs. dry feeders and nipple drinkers separate from the feeder. The Kansas workers reported total water disappearance of 6.25 L/pig/d for the dry feeders vs. 4.16 L/pig/d for the wet/dry feeder from 48 to 83 kg live weight. The Nebraska workers reported total water disappearance of 6.06 L/pig/d for the dry feeders vs 4.50 L/pig/d for the wet/dry feeders from 19 to 108 kg live weight.

Several studies have indicated that one model of wet/dry feeder resulted in increased intake compared to a particular dry feeder (Anderson et. al., 1990; Walker, 1990). In a summary of several on-farm tests, Payne (1991) concluded that the wet/dry feature resulted in increased growth but no increase in apparent feed intake. However, he suggested that the level of feed wastage may have been less in wet/dry feeders and that actual intake may have been higher. Gonyou and Lou (2000) compared feed intake and growth from six models of wet/dry feeders with that of six models of dry feeders. The wet/dry feature resulted in a 5% increase in both feed intake and growth rate.

WATER USAGE

As noted above, the decisions as to feeder design often include considerations regarding water disappearance and manure volume. In a series of trials, Brumm et. al. (2000) investigated several feeder and drinker combinations for their impact on pig performance, water usage and resultant manure volume. (Table 4). While not directly compared, water savings (and resultant manure volume reductions) appear to be similar for the wet/dry feeder investigated and the dry feeder and cup drinker based on water:feed ratios.

Brumm and Mayrose (1991) examined the impact of flow rate and pigs per drinker on performance (Table 5). They concluded that while differences in performance existed between the research centers, a delivery rate of more than 250 ml/min is advisable for finishing pigs. The rate of 1000 ml/min appears to be more than adequate, especially if water conservation is a concern. The results also suggested that one nipple drinker per 16 or 22 pigs per pen was inadequate.

These results suggest total water disappearance is considerably less than the estimates currently in the literature. For example, the Midwest Plan Service (MWPS, 1991) suggest a growing-finishing pig uses between 12 and 16 liters of water per day. Recent Australian data reported 17 liters of water use for all purposes per kilogram of liveweight sold (Australian

Pork Limited, 2002). In the above experiments, maximum water used was just over 6 liters per pig suggesting considerable water usage on pig farms not associated with pig needs.

Table 4. Effect of feeder and drinker decisions on performance, water use and manure volume (Brumm et. al, 2000).

	Exp 1, Feeder type		Exp 2, Drinker type		Exp 3, Drinker type	
Item	Wet/dry	Dry	Swinging	Nipple	Swinging	Cup
Pig wt, kg						
Initial	18.6	18.5	18.2	18.3	17.5	17.4
Final	108.0	107.4	110.0	109.9	115.1	113.9
Daily gain, kg	0.780[a]	0.760[b]	0.754	0.748	0.831	0.820
Daily feed, kg	2.379[a]	2.250[b]	2.302	2.307	2.118	2.043
Feed:gain	3.049[a]	2.959[b]	3.086	3.058	2.551	2.494
Water, L/pig/d	4.49	6.06	4.90	5.50	5.01	3.78
Water:Feed, kg:kg	1.78[a]	2.79[b]	2.34[a]	2.64[b]	2.41[a]	1.89[b]
Manure volume, L/pig/d						
Summer	4.96	7.02				
Winter			3.96	4.59		

[a b]Means within experiment differ, $P<0.05$.

Table 5. Effect of flow rate and number of pigs per nipple drinker on finisher pig (59 to 105 kg) performance (Brumm and Mayrose, 1991).

		Flow, ml/min		Number of pigs/nipple	
Item	Location	250	1000	8 or 11	16 or 22
Daily Gain, kg					
0-28 d	University of Nebraska	0.727[a]	0.777[b]	0.790[c]	0.712[d]
	Purdue University	0.614	0.641	0.655	0.595
Overall	University of Nebraska	0.773	0.814	0.818	0.768
	Purdue University	0.645	0.650	0.655	0.641
Feed:Gain					
Overall	University of Nebraska	3.66	3.54	3.55	3.65
	Purdue University	3.61	3.59	3.54	3.65

[a,b]$P<0.1$; [c,d]$P<0.05$

REMOVAL AND REMIXING OF LIGHTWEIGHT PIGS

Managing variation in pig weight has major consequences for pig flow. Many producers routinely overstock pens at placement, sorting off the lightest weighing pigs and remixing these pigs at some point during the first three to eight weeks following placement. They follow this management practice in the belief that removing the lightest pigs from a pen and remixing with other lightweight pigs results in better overall pig performance for the population of pigs placed in the facility and possibly better facility utilization.

Recently, the NCR-89 Committee on Swine Management tested this management practice in both wean-to-finish and grow-finish production flows (Brumm et al, 2002). In two experiments, the following treatments were applied to populations of pigs:

1) 15 pigs/pen from initial weight to slaughter (15S),
2) 20 pigs/pen from initial weight to 3 weeks post weaning for wean-to-finish or the week the population weighed 68 kg for grow-finish and then reduced to 15 pigs/pen to slaughter (20/15), and
3) 15 pigs/pen comprised of the 5 lightest pigs from each of three 20/15 pens (15M).

In each study, corn-soybean meal diets were based on the mean weight of the population of pigs, rather than based on individual pen weights. Thus, the lightweight pigs did not receive any special diet or other management following remixing, a practice that is typical of many production facilities.

The populations compared were the population that was sorted and mixed (20/15 + 15M) versus the population that was never sorted (15S). Sorting the lightest weight pigs was effective in reducing the within pen weight variation at the time of sorting (Tables 6 and 7), but had minimal effect on reducing within pen weight variation at day 158 post weaning for the wean-to-finish trial or when the first pig in the pen weighed at least 114 kg for the growing-finishing trial.

Figure 1 displays the variation in pig weight of each population on day 158 when the heaviest pigs in the wean-to-finish facility were removed for slaughter. The sorted and mixed population is represented in both ends of the population weight curve, while the unsorted population is not represented in either the two lowest weight or the heaviest weight groupings.

Table 6. Effect of sorting and removal on wean-to-finish pig performance (Brumm et. al, 2002).

	Treatment		
Item	20/15	15M	15S
Pig weight, kg			
Weaning	4.8		4.8
Day 21 - presort[a]	9.0		9.5
Day 21 - postsort[b]	9.7	7.0	9.5
Day 158 post weaning[a]	116.9	110.5	115.1
Coefficient of Variation (pig weight within pen), %			
Day 21 – presort	19.5		17
Day 21 - postsort[b]	13.7	11.3	17
Day 158 post weaning	7.6	7.9	6.9

[a] Treatment effect, P<0.05
[b]20/15+15M vs 15S, P<0.01

Table 7. Effect of sorting and removal on finishing pig performance (Brumm et al, 2002).

Item	Treatment 20/15	15M	15S
Pig weight, kg			
Placement	26.2		26.2
Presort and removal	72.9		70.8
Postsort and removal[a]	74.1	61.6	70.8
Coefficient of Variation (pig weight within pen), %			
Placement	13.4		13.3
Presort and removal	10.2		11.4
Postsort and removal[b]	9.2	8.6	11.4
First pig removed[b]	8.2	8.7	10.2

[a] Treatment effect, $P<0.01$
[b] 20/15+15M vs 15S, $P<0.05$

Figure 1. Effect of sorting and mixing treatments on pig weight on day 158 post-weaning in a wean-to-finish facility (Brumm et. al, 2002).

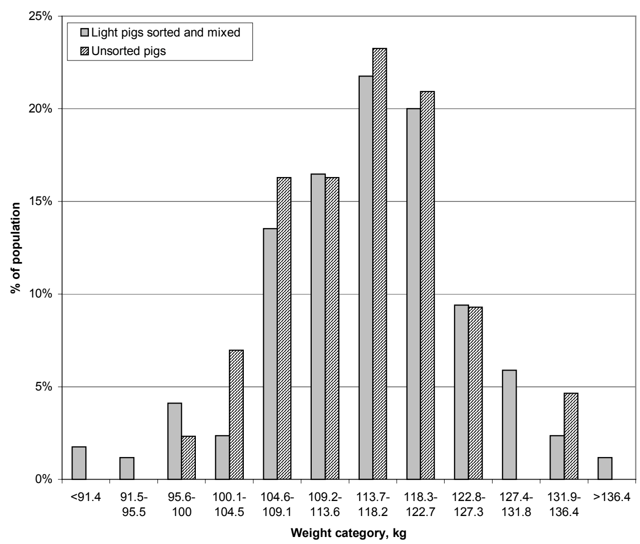
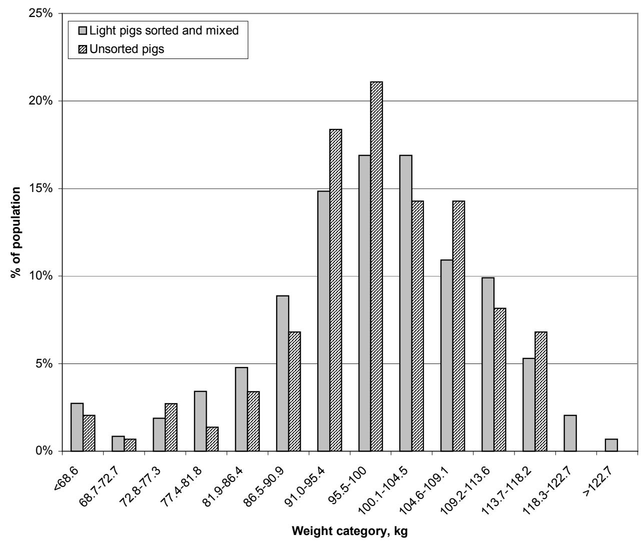


Figure 2 is a similar display of weight variation in each population when the first pig was removed on the week it weighed 114 kg or more for the grow-finish trial. This data has more spread since it represents the combined data of pigs at the University of Nebraska, University of Minnesota, University of Illinois and Iowa State University. However, the overall pattern is the same. That is, no pigs in the unsorted population were in the heaviest weight category and a greater number of pigs in the lightest weight categories. In the grow-finish study, 14% of the pigs in the sorted population weighed less than 87 kg versus 10% of the unsorted population.

Figure 2. Effect of sorting and mixing treatments on pig weight the week the first pig in a pen weighed at least 114 kg, grow-finish study (Brumm et. al, 2002).



In the grow-finish study, pigs were removed for slaughter on the week they weighed 114 kg or greater. Beginning the week when 50% or more of the pigs had been removed from a pen, the remaining pigs were fed for up to 3 weeks or until the pen averaged 114 kg. Using this method to market pigs, the pens that had the pigs removed had average days to empty of 108 following placement, and the pens that had the mixed pigs had average days to empty of 125. This compares to a 118 day average days to empty for the unsorted pigs. In this study, it took 7 days longer (125 vs 118) to empty the last pen for the population of pigs that had the lightweight pigs removed and remixed versus the population where the lightweight pigs were not removed.

In these studies, removal and mixing of the lightweight pigs did not decrease the variation in population weight, nor did it improve facility utilization as measured by the days to pen empty in the grow-finish trial. There are several possibilities for why this common management practice is not effective.

When the lightweight pigs were removed and remixed, they had to learn new pen mates, pen social structure and new pen location. All of this probably contributed to a period of time in which there was minimal feed intake and growth. When they achieved a stable social structure, variation in the pen increased to that of other pens since some pigs in the pen became dominant, some submissive and some unsure as to their social status.

For the pens where the pigs were removed, similar social disruptions occurred. While the pigs remaining in the pen did not have to become acquainted with a new pen, the removal of the lightweight pigs most likely resulted in the removal of the lowest social ranking pigs. With their removal, one or more of the remaining pigs in the pen acquired the low social rank. This most likely explains why sorting and removal was not effective in changing within pen variations in weight at slaughter.

It is possible that results may have been different if the lightweight, remixed pigs had been offered a diet formulated to more closely match their nutritional needs versus a diet formulated to the average needs of the population. Results may also differ if the heaviest or midweight pigs are removed and remixed.

SORTING BY WEIGHT AT PLACEMENT

Another common management practice is to sort pigs by weight upon entry into wean-to-finish, nursery and grow-finish facilities. Producers do this in the belief that pens of pigs begun at uniform weights will have less variation at slaughter weight and may have better daily gain.

When this management practice was first utilized in confinement facilities, it made sense considering the farrowing/weaning practices common to the industry. When farrowing and weaning were continuous flow events on hog farms, sorting by size also implied a sorting by age. Thus, sorting by size was a management tool to minimize the age variation within a pen of pigs. However, in a majority of today's North American production systems, age variation with a facility is often minimal. It is not uncommon to put 1000 pigs into a growout facility with no more than 3 days in age variation among all the pigs.

Recent research has reexamined the practice of sorting by size at the time of placement. There are now several studies that have examined the impact of sorting pigs by size (light, medium and heavyweight or light and heavy) at placement versus placing light and heavy pigs in the same pen on performance to slaughter (Tindsley and Lean, 1984; Francis et. al, 1996; O′Quinn et. al, 2001).

Typical of these studies are the results of O'Quinn et. al. (2001) that are presented in Table 8. While sorting by size was effective in reducing the within pen weight variation at placement on day 0, there was no difference in within pen weight variation on day 91. Similarly, Tindsley and Lean (1984) reported that coefficients of variation for within pen weight didn't change from placement to slaughter when pigs were placed in pens with large weight variation initially. However, variation increased within pens when pigs were placed in pens with minimal within pen weight variation.

As a result of these data, the recommendation is to not sort pigs by size upon placement into a growing-finishing facility, nursery or wean-finish facility. The exception to this recommendation is when it is possible to use management tools to treat a group of sorted pigs in a special manner. For nurseries and wean/finish facilities, this means that it remains accepted practice to pen the very lightweight pigs together, in the expectation that they will remain on a starter diet sequence 1-5 days longer than the rest of the pigs in the facility. For grow-finish facilities where the nutrition, temperature and other management decisions are made on the basis of the average of the barn, sorting by size is not routinely recommended.

Table 8. Effect of sorting by weight at placement on pig performance (O'Quinn et. al. 2001).

Item	Treatment				P value
	Heavy	Medium	Light	Unsorted[a]	Sorted vs. Unsorted
Pig wt, kg					
Day 0	37.1	34.0	30.2	33.8	
Day 91	123.4	117.8	113.2	119.9	0.03
Within pen CV pig wt, %					
Day 0	3.4	2.3	6.8	9.4	
Day 91	6.0	6.5	8.2	7.3	
ADG, kg	0.94	0.92	0.91	0.94	0.03
ADF, kg	2.67	2.66	2.73	2.70	0.84
F:G	2.85	2.93	3.02	2.88	0.46

[a]Consisted of equal numbers of heavy, medium and light pigs within the pen

NEW THOUGHTS ON SPACE ALLOCATION

There is a vast amount of literature available on space allocation effects on performance. The earliest summary of the data was Kornegay and Notter (1984). Their literature review suggested that as space per pig declines, the largest effects are on daily gain and feed intake, with less predictable effects on feed conversion efficiency. The challenge for North American producers has been that Kornegay and Notter's review included no literature where pigs were grown to slaughter weights larger than 100 kg.

Since then, there have been several studies examining the effect of space allocation to heavier weights (NCR-89, 1993; Brumm and NCR-89, 1996). In addition, consideration is now given to the economic consequences of the space allocation decision (Powell and Brumm, 1992; Powell et. al, 1993). In general, the North American swine industry balances the reductions in performance with the economics of facility flow by stocking fully slatted barns at 0.69 m^2/pig.

However, recent research is causing many production systems to rethink the potential response to space allocation. Brumm et. al. (2001) suggest that the response to space allocation may depend on when the social group (pen mates) was formed. Their study examined the potential interaction of nursery space allocation and grow-finish space allocation when pigs are moved from the nursery to grow-finish at approximately 20 kg. When pigs were mixed and new social groups created upon movement from the nursery to the grow-finish facility, pigs responded to space restriction by reducing feed intake and daily gain (Table 9). However, when social groups remained stable (pens of pigs moved to grow-finish facility with no remixing), there was no effect of space allocation on gain, feed intake or feed conversion (Table 10).

Brumm et al. (2001) concluded that the literature available on the effects of space allocation (such as Kornegay and Notter, 1984) reported on trials where pigs were mixed at the beginning of the experiment to create uniform social groups. However, many production systems maintain pen identity (either by moving entire pens or as wean-finish) between nursery and grow-finish phases of production and thus may not experience as dramatic an effect of space allocation as predicted in the literature.

Table 9. Interaction of nursery and grow-finish space allocation when pigs are mixed at move from nursery (Brumm et. al, 2002).

	Space allocation, m^2/pig				P Values	
Nursery:	0.16		0.25			
Item Grow-finish:	0.56	0.78	0.56	0.78	Nursery	Grow-Fin
Pig wt, kg						
Weaning	6.6		6.6			
From Nursery	19.4		20.9		<0.001	
Daily gain, gm						
Nursery	364		408		<0.001	
Grow-finish	817	849	781	867		<0. 001
Grow-finish ADF, kg	2.533	2.589	2.465	2.665		0.002

Table 10. Interaction of nursery and grow-finish space allocation when pigs are not mixed at move from nursery (Brumm et. al, 2002).

	Space allocation, m^2/pig				P Values	
Nursery:	0.16		0.23			
Item Grow-finish:	0.60	0.74	0.60	0.74	Nursery	Grow-Fin
Pig wt, kg						
Weaning	5.4		5.4			
From Nursery	21.4		22.7		0.001	
Daily Gain, gm						
Nursery	403		430		0.001	
Grow-Finish	821	821	827	831		NS
Grow-finish ADF, kg	2.386	2.419	2.398	2.433		0.023

CONCLUSIONS

Housing decisions involve both decisions regarding capital expense such as feeders and drinkers and decisions regarding daily management such as sorting and mixing and removal for poor growth. As demonstrated by the data from the University of Nebraska, great strides have been made in grow-finish pig performance in the past 20 years. As we continue to learn more about the pig's behavioral preferences and its response to the limitations we may impose such as space or temperature, we can expect to see as great or greater improvements in the next 20 years.

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OBSERVATIONS ON AUTOMATIC SORTING

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ABSTRACT

Automatic sorting technology (AST) is a relatively new concept that is being implemented at many farms today. The concept revolves around using weigh scales situated in the barn such that pigs walk through them, are weighed and automatically sorted aside if they have reached market weight. In so doing, the producer is more confident that pigs are being marketed at their target weight. This technology can have substantial economic benefit, depending on the producer's ability to visually estimate weights and sort pigs, and on the packer's payment schedule. The technology is not without its challenges and requires training for both the producer and the pigs.

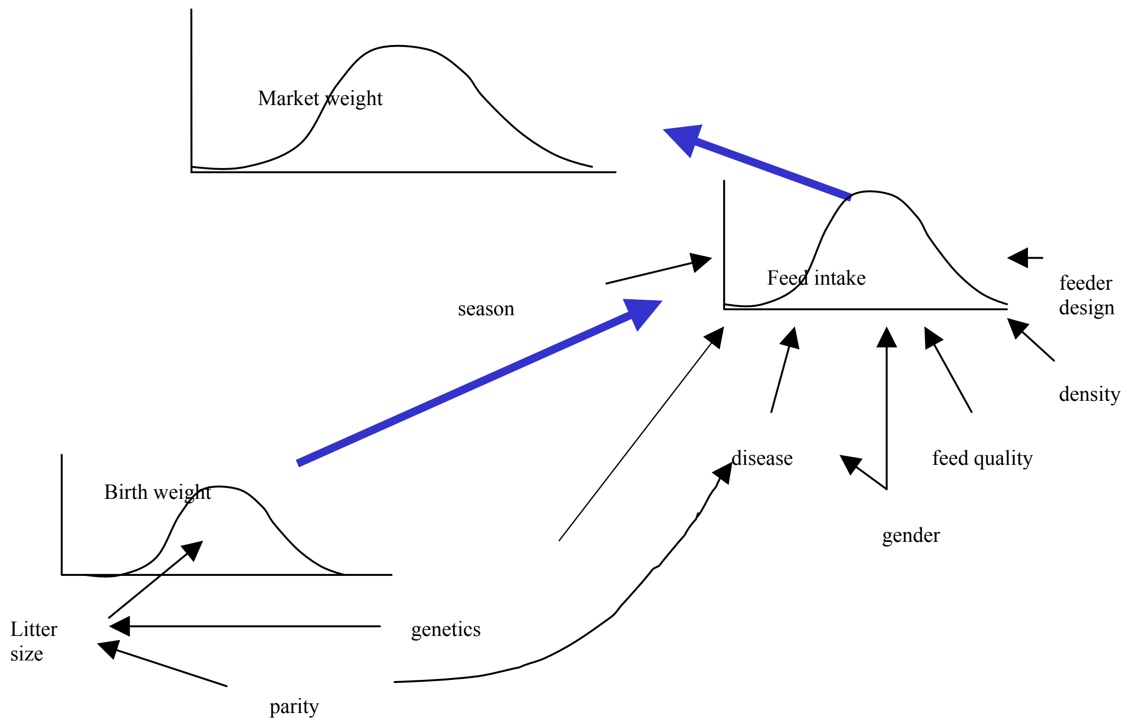
INTRODUCTION

Your packer tells you that the carcasses should be between a certain low weight and a high weight to receive the lowest sort loss and maximum lean premium. But is your packer's target weight for your pigs the same as your calculated target weight? Probably not. So your first challenge is to calculate the optimum weight for your pigs, given your packer's payment schedule.

A second challenge is that there is a major financial difference between attempting to sell between the specification limits that a packer calls for and pursuing an optimum market weight. A Japanese professor named Taguchi demonstrated this to us by use of what is now called the Taguchi loss function. This is a simple, but very powerful concept. There is an optimum market weight where margin is maximized. However because of sorting difficulties and transportation schedules, we usually shoot for a market weight range. Reducing the variability of market weight at slaughter and having carcasses as close as possible to the calculated optimum, represents extra money for you that we usually leave on the table.

What influences variability in market weight? Figure 1, describes the important drivers of variability in market weight. Quality control programs in manufacturing have taught us that it is much cheaper to reduce variability early in the process rather than by rejecting nonconforming product at the end. We experience this in producing pigs. The more variable growth is within a group of pigs, the more difficult it is to manage the selling of those pigs. We know that by reducing sources of variability early in the growing phase, we will reduce variability in weight when the pigs reach approximate market age. Camille Moore has suggested that there are two major drivers of variability at market – variability in birth weight and variability in subsequent feed intake. We can diagram the variables influencing these two drivers as follows.

Figure 1. Factors influencing variability in market weight.

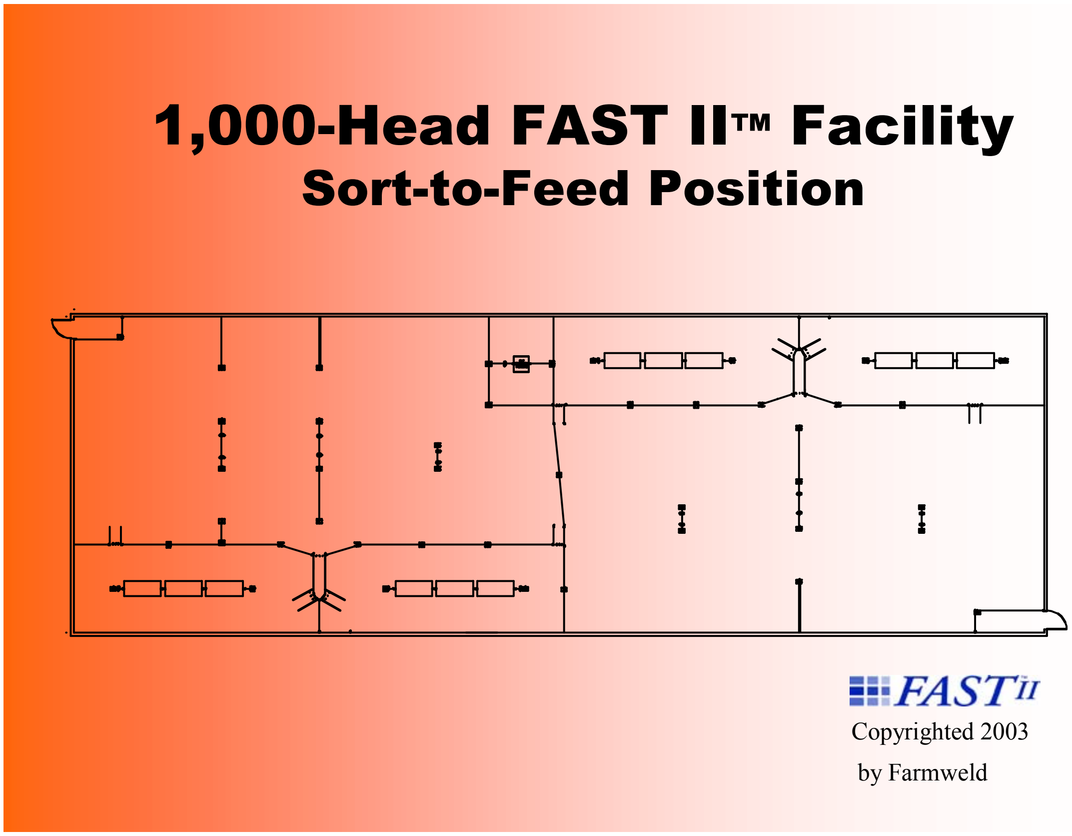


BENEFITS OF AUTOMATIC SORTERS

Automatic sorting, using an in-pen weigh scale, is an old idea that has been brushed off and is being rejuvenated. What has changed to make this a worthwhile concept to re-visit? Firstly, we now are more comfortable with large pen or group sizes. When I walk through a barn with large groups and automatic sorting capability, I am struck by how calm and approachable the pigs are. Secondly, the packer's specifications for avoiding sort loss are tightening. Margins are ever decreasing making it compulsory that we look for every opportunity to remain competitive.

Basically, the idea of automatic sorting is that a weigh scale is placed in the pen and pigs walk through the scale to get to the feeding area (Figure 2). While there are many possible designs, the barn is often laid out in one or two large size pens (~300-600 / pen). A scale head is attached to the scale and programmed to direct pigs in one of two directions upon exiting the scale – to the feeding area or to the shipping area of the barn. With this system, all pigs weighing at least the cutoff weight will be detected and sorted for shipping. The frequency of automatic sorting and shipping then will dictate the ultimate variability in market weight. It appears that after the producer is experienced, average feed intake and gain can be maintained at historic levels.

Figure 2. Example of barn layout for automatic sorting (kindly provided by Farmweld).



If we had perfect human sorters, this technology would not be needed. But because people vary in their ability, this technology has a role. The reduction in variability and consequent increased margin earned / pig must offset the cost of the equipment plus installation. Some farms may experience labor savings if they are currently spending time weighing pigs to achieve optimal marketing. If a farm is not weighing pigs, there will probably not be labor savings because labor saved in the marketing of pigs is replaced with labor needed to train pigs and assure that they are adapted to the sorting system. Data are beginning to trickle in comparing automatic sorting to traditional barns (Tables 1, 2 and 3).

Early numbers indicate a payback period of approximately 2 years, but this will vary among farms. Other advantages include:

- able to sort to feed light and heavy pigs different diets,
- pigs appear to have less stress at loading for market,
- better space utilization of the barn,
- can have 12-24 hour feed withdrawal,
- less labor for sorting, and
- lower gating costs (offset by cost of equipment).

Table 1. Data from a Purdue comparison of automatic sorting and traditional barns (no significant difference).

	No. head	Average Daily Gain	Feed Efficiency	Mortality
Automatic sort	1859	1.84	2.76	4.62%
Traditional	2,474	1.80	2.63	3.05%

Table 2. Data from one 1200 head wean-to-finish barn in Minnesota compared to traditional.

	No. head	Average Carcass Weight (lbs.)	Price (including premiums and discounts)
Automatic sort	1150 sold	204	104.9%
Traditional	37,089 sold	199.2	101.6%

Table 3. Estimated economic value of automatic sorters (Prairie Swine Center, March 2004).

	Value ($/pig)
Sort loss reduction (70% core → 90% core)	3.50
Demerit reduction (50% reduced demerits @ $.75 ea)	0.38
Feed budget by weight (could be $2.50/pig)	0.00
Phase feeding (could be $2.50/pig)	0.00
Feed restriction at market (3 kg less feed in last 12 hrs)	0.48
Stocking density, reduced alley & pen divider	0.83
Labor at loading (1.5 person-hrs vs 4 for 240 pigs)	0.16
Less penning	0.53
Less feed auger	0.05
Full slat (slatted floor adds $30/pig space)	-0.61
Sorter ($9,000 installed)	-0.55
Net savings	$4.77

Automatic sorting is not without its challenges. The equipment set-up needs to be done correctly. This includes space allocations, barn layout, and placement of gating. Then, the producer needs to learn how to run the equipment. And finally, the pigs in every group need to be trained. Failure of any one of these 3 elements, and we have a significant added cost, not benefit.

CONCLUSIONS

In the last 25 years, our industry has gone through revolutionary change brought about by technical and strategic innovations (Table 4). In my view, automatic sorting is a technology that will be added to the list of those having a significant impact on the industry. It will be a classic example where early adopters capture the most economic advantage. Then, as more producers tighten their marketing capability, packers will offer less incentive and more penalty for missing their specifications. Effective marketing will become an expectation of being in the pork business, and the reward will be remaining cost competitive.

Table 4. Technical and strategic innovations in the swine industry.

Technical innovations	Strategic Innovations
Batch farrowing and all in, all out pig flow	Production contracting
Lean genetics	Vertical integration
AI	Market contracts
Parity segregation	Differentiation of pork products
Effective marketing	

FACTORS ASSOCIATED WITH IN-TRANSIT LOSSES

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ABSTRACT

A number of factors are known to affect the amount of stress that pigs experience during transport. Stressful conditions during transport, handling and holding may lead to in-transit losses including death, increases in the number of subject animals and reductions in meat quality [Clark, 1979; Lambooj, 2000; Tarrant, 1989]. For this paper, the term "in-transit losses" will be used to describe the death of a healthy market pig between the time it leaves the farm up to the time it reaches the processing line at the packing plant. The purpose of the research was to describe the in-transit losses experienced in market pigs in Ontario and to identify the association between losses, distance, weather, and phase of marketing. In 2001, 0.17% or 17 out of every 10,000 pigs marketed died during transport. The farm where the pig originated explained 55% of the variation in this loss. The packer and transporter explained 25% and 19% respectively. Most of the losses occurred in the summer. Both temperature and humidity were related to in-transit losses. Distance was not related to losses.

INTRODUCTION

In-transit losses are of concern to each of the marketing sectors; the producer, transporter and packer. In Ontario there is an In-Transit Loss Committee with representatives from Ontario Pork and each of the marketing sectors. In an effort to reduce the losses, they recommended that research be conducted in Ontario to determine the factors associated with these losses. Although there has been extensive research conducted in the United Kingdom, similar research has not been conducted in North America. Both the weather and the distances traveled in Ontario differ from that in the UK. Therefore this research will have significant practical implications to the transport of Ontario pigs. It is likely that the results will also relate to other areas of North America with similar conditions.

DESCRIPTION OF LOSSES

Ontario Pork collects data about market pigs based on booking numbers. Each booking number described the number of pigs marketed from one or more producers on trucks owned by a given transport company and delivered to one packer. The booking number has an associated expected time of arrival at the packers. Weather data including hourly temperature and humidity recordings was purchased from Environment Canada and a similar source from the United States. The weather station closest to the packers was used to represent the environmental conditions for a given group of pigs. Mixed model analyses were used to determine the association between various factors and the in-transit loss ratio. This ratio was measured as the number of in-transit losses divided by the total number of pigs that were included in the booking number.

In 2001, there were 4,760,213 finisher pigs marketed in Ontario and of those 7,969 pigs died during transport. This amounts to a loss of 0.17% or 17 pigs in every 10,000. A subject pig is one which is recognized as being abnormal or ill at some point during the transport chain. A report is generated when a subject pig is identified. If the pig dies during transport, then an in-transit loss report is created. If the pig continues through the transport chain and is processed at the packers, then the original subject information is discarded. Of the in-transit losses, 15% of the pigs were identified as subject pigs sometime during the transport chain. However, because subject pigs are not individually identified, this may be an inflated value. It may be that 15% of the time a pig was identified as subject on a booking number where a pig ultimately died. There is a complicated flow of pigs from farm to packer. Many farms will use more than one transport company and many transport companies deliver pigs to multiple packers.

FACTORS ASSOCIATED WITH IN-TRANSIT LOSSES

Producer

In-transit losses varied by producer, transporter and packer but the largest amount of variation was due to the producer. In other words, the farm of origin explained more of the variation or change in the amount of in-transit loss than the transporter or packer. Ten percent of producers lose at least 4 pigs per 1,000 pigs marketed, whereas 25% of the producers did not have any in-transit losses.

Thus we expect that a transporter might deliver one producer's pigs and expect no losses but when that same transporter delivers another producer's pigs, some pigs will die. The design of the facilities at each point of loading and unloading and the pre-transport management of pigs on the farm can also affect the levels of stress in pigs [Grandin and Lambooj, 2000]. Genotype, together with stressful ante-mortem handling, significantly affects the tendency for PSE, while DFD is affected less by genetics and mainly by transport conditions. Pigs are extremely susceptible to motion sickness, which can lead to vomiting and death through choking [Bradshaw, 1996]. Current Codes of Practice recommend that pigs have feed withdrawn 3-4 hours prior to loading [Canadian Agri-Food Research Council, 2001]. Other sources recommend withholding of feed for 16-24 hours before slaughter, or depending on distance to packing plant or assembly yard, stopping feeding the night before transport [Lambooj, 2000]. Feed and water withdrawal times have been identified as a critical area in need of research in the Transport Codes of Practice [Canadian Agri-Food Research Council, 2001].

Transporters

Factors associated directly with the transporters only explained 19% of the variation of in-transit losses, although 55% of the losses occur on the truck and appear to be a direct result of this phase of marketing. It appears that the losses are relatively consistent across transport companies. A number of factors are known to affect the amount of stress that pigs experience during transport. These include loading density, weather, microclimate in the truck, and duration and route of transport [Lambooj, 2000; Warris, 1998]. Truck design and transport routes that result in frequent stopping can significantly influence the microclimate in trucks. Current Codes of Practice recommend a 25% reduction in loading density of pigs in hot humid weather. Genotype, together with stressful ante-mortem handling, significantly affects the tendency for PSE, while DFD is affected less by genetics and mainly by transport conditions [Warris, 1998]. To date, the interactions of loading density with weather conditions has not been investigated under Ontario climatic conditions.

Packers

Factors associated directly with the packers explained 25% of the variation of in-transit losses. Ten percent of packers had losses of at least 0.21% whereas 25% of packers had losses of 0.02% or less. Trucks having to wait in the yard at the packers prior to unloading increases the temperature stress to the pigs. These animals are at the end of the travel time and, without flow of air to the truck, may be exposed to high temperatures especially on very hot summer days. Stress increases when fighting occurs after groups of unfamiliar animals are mixed in holding pens at assembly yards and packing plants. The management of pigs at packing plants can also affect the levels of stress in pigs [Broom, Grandin, Lambooj, 2000]. Stress and fatigue before slaughter can lead to physiological changes in muscle tissue (acidification and energy stores) that result in post-mortem reductions in meat quality. Stress before slaughter can also affect the microbiological contamination of carcasses.

Weather

Most of the in-transit losses occurred in the summer. Although the yearly average losses were 0.17%, once temperature reached 20^{o}C the losses were 0.4%. Between 26 and 28 ^{o}C, the losses were 0.6%, and above 28 ^{o}C, they were 0.76%. The impact of temperature and humidity combined to increase these losses. The impact of an environmental temperature of 28^{o}C and a humidity level of at least 60% was the same as a temperature of 36^{o}C and a humidity level of less than 30%. At high humidity levels, losses occurred at lower environmental temperatures. Pigs have difficulty maintaining body temperature in hot conditions [Lambooj, 2000]. The stress and excitement of handling increases heat production rates making transported pigs even more susceptible to heat stress, with some genotypes being much more sensitive than others [Murray, 1998; Schrama, 1996]. Most livestock trailers do not have mechanical ventilation and require truck movement for air flow through the animal compartment [Lambooj, 2000].

CONCLUSIONS

In 2001, in-transit losses were experienced by 17 of every 10,000 market pigs. The majority of these losses occurred in the summer when a combination of moderate temperatures with high humidity or high temperatures with lower humidity both likely caused stress to the pig during transport. There is a lot of farm-to-farm variation in in-transit losses. Further research must focus on the cause of the losses in these problem farms. Clearly a major factor causing in-transit losses is the environmental conditions during the summer. We need to conduct further research under Ontario conditions to determine how to reduce this stress to the pigs.

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NUTRIENT MANAGEMENT

NUTRITIONAL STRATEGIES TO MINIMIZE NUTRIENT OUTPUT

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ABSTRACT

In many areas of the world the contribution of animal agriculture to environmental pollution has become a serious concern. Through science-based nutritional strategies, the mineral balance on pig farms can be substantially improved. Most of these strategies are quite simple to implement and can have a significant impact on profitability as well. The most promising and practical of these strategies focus on two main principles - minimizing input and maximizing the efficiency of utilization. Using phytase, replacing protein with synthetic amino acids, and by feeding more closely to the animal's requirements, nitrogen and phosphorus excretion in pig manure can be reduced by up to 50%. Application of nutritional strategies to reduce mineral excretion will increase the need for accurate evaluation of available nutrient content in pig feed ingredients, precise feed formulation and manufacturing.

INTRODUCTION

In areas with intensive pig production, the negative impact of pig production on the environment is one of the main factors that limits the expansion of the pork industry and affects the attitude of the general public towards animal production (e.g. Kornegay and Verstegen, 2001). In several countries legislation has been introduced, or recommendations have been made, to reduce or to minimize the contribution of animal agriculture to environmental pollution. These imposed regulations, or recommendations, generally increase production costs and have forced the agricultural industry to seek means to reduce the production of animal waste.

This paper discusses the general principles of nutrition as it relates to nutrient management and focuses on ways of manipulating the pig's diet and the feeding program to reduce the excretion of nutrients in pig manure. The nutrients of prime concern are copper (Cu), zinc (Zn), nitrogen (N) and phosphorus (P). Potassium (K) should be considered as well, as it affects the fertilizing value of manure.

COPPER AND ZINC

In general, Cu and Zn in pig diets are much higher than the minimum requirements for normal performance (i.e. 5-25 ppm Cu and 50-125 ppm Zn for the various classes of swine; National

Research Council, 1998). These minerals act as growth promotants when included at levels much higher than minimum requirements. In Canada, the federal Feeds Act limits the maximum level of Cu and Zn in the diet to 125 ppm and 500 ppm respectively, but in the US, much higher levels are common. In some countries, like the Netherlands, growth promoting levels of Cu and Zn are no longer allowed in finisher pig diets due to the impact on the environment. As long as minimum requirement levels of Cu and Zn are maintained, the excretion of these minerals in pig manure is not a concern; the focus then switches to N and P excretion.

MINERAL BALANCES

The efficiencies by which animals use nutrient intake for mineral retention in useable animal products are generally low. On swine farms, the efficiency of K retention is very low (3.6 to 10%) while the efficiency is somewhat higher for N and P retention (18 to 40%)(Table 1). Overall, approximately two-thirds of N and P intake is excreted in manure. Starter pigs are slightly more efficient while sows are less efficient. However, since grower-finisher pigs produce the majority of the manure on a typical farrow-to-finish operation, typical values for these operations would be similar to the values shown for grower-finisher pigs. This extremely low level of efficiency and between farm variability leaves room for decreasing mineral excretion by improving the efficiency of retention in the pig (de Lange, 2002).

Table 1. Typical mineral balances (kg/animal) on Dutch pig farms (Jongbloed, 1991).

	Nitrogen	Phosphorus	Potassium
	I. Growing pigs (25-106 kg live weight)		
Dietary levels (%)	16.7*	.52	1.22
Intake (kg/pig)	6.36	1.23	2.90
Excretion (kg/pig)	4.48	.83	2.73
Retention (kg/pig)	1.88	.40	.17
Efficiency of retention (%)	29.5	32.5	6.0
	II. Sows, including nursing piglets		
Dietary levels (%)	15.7*	.59	1.32
Intake (kg/sow/yr)	27.57	6.53	14.52
Excretion (kg/sow/yr)	22.50	5.5	14.0
Retention (kg/sow/yr)	5.07	1.03	.52
Efficiency of retention (%)	18.4	15.8	3.6
	III. Starter pigs (9-25 kg live weight)		
Dietary levels (%)	18.4*	.67	1.25
Intake (kg/pig)	.94	.21	.40
Excretion (kg/pig)	.56	.13	.36
Retention (kg/pig)	.38	.08	.04
Efficiency of retention (%)	40.5	39.4	10.0

*Crude protein (N x 6.25) rather than N levels.

Variation in the amount of minerals excreted with manure between farms can be attributed to various animal and feed factors. These include:

- feed usage and feed wastage
- the level and digestibility of amino acids and P in the various diets
- the minimum amounts of N and P required by the pig for basic body functions (maintenance requirements)
- the (marginal) inefficiency of utilizing amino acids and P that are supplied over maintenance but below maximum N and P retention in the pig's body
- the balance of amino acids supplied in the diet vs. the balance of amino acids required
- the rate of N and P retention in the pig's body

Given the large variation between farms and environmental pressures, the need to closely monitor N and P balances on individual pig units will increase. This can be best accomplished by closely monitoring the amount and composition of feeds, or feed ingredients, that are used and the number and weight of animals that are removed from the farm. In the Netherlands, such a mineral book-keeping system is obligatory for farms that have more than 2.5 large animal units (about 10 growing-finishing pig places) per hectare of land, and requires that feed companies provide statements regarding amounts of nutrients that are delivered to each farm. With this approach, the calculated nutrient balances are rather sensitive to initial and final nutrient inventories with feed and manure (MINAS, 2002).

In Ontario, this approach to calculating nutrient balances has been integrated into 2 computer programs used to accurately predict the excretion in manure of the minerals of concern (N, P, K) in environmental pollution (Birkett and de Lange, 1998; NMAN, 2003). In this approach, N, P and K excretion in pig manure is calculated from the difference between the amounts of N, P, and K that are fed to the animals (based on amounts of various feeds used and the N, P, and K content in the various feeds) and the amounts of N, P, and K removed from the farm in animals (based on the number of pigs in each category, live and dead, that are removed from the farm) (Birkett and de Lange, 1998). NMAN is a software tool developed by the Ontario Ministry of Agriculture and Food that assists farmers in predicting nutrient generation, based on manure analysis or database values, and determining land base requirements for agronomic use of nutrients (NMAN, 2003).

LOWERING NITROGEN AND PHOSPHORUS EXCRETION THROUGH NUTRITION

Over the last ten years some extensive reviews have been published in which various nutritional means to improve the efficiencies of N and P retention in pigs are addressed (eg. Verstegen et al., 1993; Lenis and Jongbloed, 1995; Coelho and Kornegay, 1996; National Research Council, 1998; Kornegay and Verstegen, 2001; van Kempen and van Heugten, 2001; Ferket et. al., 2002). In this paper, only the main and most relevant means to improve the efficiency of N and P retention will be discussed. Other means, including plant breeding (to manipulate feed ingredients from plant origin), feed ingredient selection, and use of enzymes other than phytases are discussed elsewhere (eg. Verstegen et. al., 1993; Lenis and Jongbloed, 1995; Coelho and Kornegay, 1996; National Research Council, 1998; Kornegay and Verstegen, 2001).

The three most expensive components of a swine ration are N (an important component of protein and amino acids), P and energy. Nitrogen and P are also the most important contributors to pollution from swine manure, so it is important to maximize the efficiency with which these nutrients are used. Excretion of N and P in swine manure can be substantially reduced by a number of strategies.

Improve Feed Efficiency

Improved productivity is the most obvious strategy for reducing nutrient excretion. In general, a better feed efficiency leads to a lower excretion of N and minerals. An improvement in feed conversion of 0.25 units would reduce N excretion by 5 to 10% (Coffey, 1996). Over the past 20 years, the feed efficiency of pigs growing from 25 kg to market weight has gradually decreased from approximately 4.0 to less than 2.85 in top-producing herds.

Reduce Feed and Water Wastage. Although often overlooked, a significant amount of feed nutrients may end up in manure simply because it was not consumed by the pig. Poor feeder design, improperly adjusted feeders, and feed form can contribute to a major feed wastage problem that directly impacts on nutrient output. Research in this area has estimated that feed wastage can range from 2-20%, with typical operations at 5-6% (Gonyou and Lou, 1998). In general, N and P in manure will increase by 1.5% for every 1% increase in feed waste (Ferket et. al., 2002). If there is a noticeable amount of feed on the floor, at least 10% is being wasted. To limit feed wastage producers can feed pelleted rations, pay close attention to feeder design, and adjust feeders properly. A good general guideline is to manage feeders so that only 50% of the bottom of the feeder is covered (van Kempen and van Heugten, 2001).

Water wastage does not affect the amount of nutrients excreted, but it will adversely affect manure processing and increase manure volume and disposal costs (Ferket et. al., 2002). The new generations of nipple drinkers have been designed to reduce water use compared to conventional nipple drinkers, which tend to be favourite play toys for pigs. Bowl or cup systems, although difficult to keep clean, also reduce water wastage. Wet-dry feeders and liquid feeding systems offer options for greater control over water use and the impact of water wastage on manure volumes.

Improve Feed Digestibility. Proper processing of feeds represents a very practical means to positively impact nutrient excretion through improvements in feed digestibility. Pelleting of feeds has been estimated to improve feed efficiency, through increased energy and protein digestibility, by 6.6% and subsequently reduce N excretion by 5% (Wondra et. al., 1995). Particle size is an area where producers can significantly improve feed efficiency. Research at Kansas State University has indicated that, for corn-based diets ranging in particle size from 1200 - 400 microns, there is a 1 - 1.5% improvement in feed efficiency for every 100 micron reduction in average particle size. Kansas State University recommends an optimum particle size for pigs of 700 - 800 microns. Other means to improve diet nutrient digestibility include the use of ingredients with highly digestible nutrients and the use of enzymes, especially phytase. These two means are presented further in this document.

It should be noted that improvements in digestibility will only improve nutrient utilization if total dietary nutrient intake is reduced. For example, recent research at Prairie Swine Centre (2002) has indicated that reducing particle size from 900 to 600 microns was effective in reducing fecal N by 11%, but not total N excretion. This is likely because feed intake was not reduced with decreasing particle size and excess digestible protein intake was broken down after absorption and excreted in urine.

Improve Animal Productivity. Pigs with improved lean growth potentials can have a better feed efficiency as a result of reduced fat tissue growth and higher carcass lean yield as compared to conventional pigs (Jongbloed and Henkens, 1996). Feed additives that promote lean tissue growth may also reduce excretion of N and P as a result of a better feed conversion compared to non-supplemented feeds. In addition, improvement in the herd health status, or in the thermal environment to which pigs are exposed, will lead to improvements in feed efficiency and thus reductions in mineral excretion. Keller (1980) estimated that converting to a specific-pathogen-free herd health status can improve feed efficiency by as much as 10% and, as a result, decrease N excretion by 10%.

Phytase

The most important anti-nutritional factor in swine nutrition, as it relates to nutrient management, is phytate. The major ingredients in pig diets are seeds (cereal grains) or products from seeds (oilseed meal and grain byproducts). However, 60-80% of the P in these feedstuffs is present in the form of phytate, a compound that pigs do not use well. Bioavailability estimates of P in corn and soybean meal for pigs range from 10-30% (Kornegay, 1996). This low availability of phytate P poses two problems for producers - the need to add inorganic P supplements to diets and the excretion of large amounts of P in the manure.

Phytate P must be hydrolyzed by an enzyme, phytase, into inorganic P before it is available to pigs. Four sources of phytases have the potential to degrade phytate within the digestive tract of pigs - intestinal phytase in digestive secretions, endogenous phytase present in some feed ingredients, phytase originating from resident bacteria, and phytase produced by exogenous microorganisms. Unfortunately, all of these potential sources have proven to have negligible phytase activity for improving phytate availability in non-ruminant animals fed corn and soybean meal based diets (Kornegay, 1996).

Phytate also impairs the bioavailability of minerals other than P. Minerals that may be bound by phytate include Zn, Cu, manganese (Mn), iron (Fe), magnesium (Mg), calcium (Ca) and chromium (Cr). Hydrolysis by phytase should release the minerals that are bound, allowing for improved absorption of Ca, Mg, Zn and Fe in pigs (Kornegay, 1996).

Research has proven that phytase added to the diet can improve P digestibility. As a result, the total P levels in the diet should be reduced to improve the efficiency of retention and reduce excretion of P into the environment by 25 - 50% (Table 2). In addition, feeds supplemented with phytase for grower-finisher pigs and for pregnant sows may need little or no supplementary feed phosphate. Currently, the addition of phytase does not appear to add more cost to the diet because it is offset by the savings associated with reducing P and Ca in the diet. Despite it being cost neutral, phytase use in Ontario remains at 20-30% compared to 70% in Quebec (de Lange et. al., 2003).

Table 2. Estimated excretion of nutrients by pigs without and with phytase (modified from Kornegay, 1998).

Assumptions for 113 kg Market Hog (birth to 113 kg):

- 306 kg of feed/pig
- 88% DM, 16.5% CP (2.64% N), 0.55% total P in diet
- 85% DM digestibility, 38% N retention, 38% P retention

Excretion per Market Hog:

- 40 kg DM [306 x 0.88 x (1 – 0.85 = 0.15)]
- 5 kg N [306 x 0.0264 x (1 – 0.38 = 0.62)]
- 1 kg P [306 x 0.0055 x (1 – 0.38 = 0.62)]

Excretion for Hogs Marketed in Ontario (5.33 million in 2003):

- 1.63 million metric tonnes of feed fed, 213,200 metric tonnes of DM excreted
- 26,650 metric tonnes N and 5330 metric tonnes P excreted

Phytase Feeding and Reduction in P Fed:

- A 0.1% unit reduction of P fed and the feeding of 500 units/kg of microbial phytase would result in 1630 metric tonnes less P excreted (1.63 million metric tonnes x 0.1%) or a 31% reduction in P excreted

Various points should be considered when including phytases in pig diets (Jongbloed and Kemme, 1990; Simons et. al., 1990; Jongbloed et. al., 1993; Coelho and Kornegay, 1996; Kornegay and Verstegen, 2001):

- Different commercial products differ in the content of active phytase. Phytase units (PTU) may be used to compare different products using a standardized test.
- The efficacy of phytases is not the same for all feed ingredients and diets. This likely reflects differences in the location within the seed where phytate is deposited, eg. in the germ in corn and the aleurone layer in wheat (O'Dell et. al. 1972).
- Not all phytases are stable when exposed to heat. During pelleting the temperature of the feed should not exceed 70-75^{o}C when uncoated phytases are included. Phytase activity should be checked in the complete, processed feed. Phytases with higher heat stability are now commercially available.
- Phytases not only increase the digestibility of P; they also increase the digestibility of Ca and other trace minerals that are tied to the phytate complex (Cu, Zn, etc.). Phytase can

improve feed utilization (by 1-2%) in starter and grower pigs by making other nutrients more available as well (eg. Mroz et. al., 1994). This results in additional "value" of added phytase.

- When determining the value of phytase, the effects of reducing the P and Ca levels in the diet should be considered. In particular, in high energy diets in which (expensive) fat is used, a reduction in mineral levels will be associated with a reduced need to use fat as there is more "space" in the feed formula. This results in reduction of ingredient costs.
- The marginal improvement in P digestibility declines with increasing levels of phytase (Kornegay and Verstegen, 2001). For example, in a low P containing diet (0.381% total P, the response to phytase is larger at low levels (less than 200 PTU/kg of feed: .021% extra dig. P/ kg of feed per 100 additional PTU) than at intermediate levels (200 to 600 PTU/kg of feed: .010% extra dig. P / kg of feed per 100 additional PTU). At high levels, improvements in P digestibility are further reduced (more than 600 PTU/kg of feed: .0035% extra dig. P/ kg of feed per 100 additional PTU). Effectively and in corn and soybean meal based diets for grower-finisher pigs, 500 PTU units can replace 0.1 percentage units of total dietary P (Kornegay and Verstegen, 2001). It should be noted that there is still some debate about the effect of pig age/weight on the response to phytase (it may be better than the indicated values at higher body weights).
- The utilization of P is affected by the Ca to P ratio in the diet; these should be maintained low (1–1.25:1 total or 2-3:1 available; National Research Council, 1998).

Formulate Based on Nutrient Availability

The bioavailability of N and P varies considerably from one feed ingredient to another (Table 3). The major reason for the inefficiency of P utilization in monogastrics is the poor digestibility/availability of P that is present in plant products, largely because much of the P in plants is in the phytate form. In contrast, the availability of P in animal and inorganic sources is much higher. For this simple reason, pig diets should be formulated on available/digestible, rather than total, nutrient basis.

Variation in nutritional value of feed ingredients is an economic and environmental concern. Without complete and timely ingredient analysis, there is a tendency for manufacturers to over-formulate rations resulting in higher ration costs and increased potential for nutrient losses. The use of book values (like those available from the National Research Council, 1998) for feed formulation will not be sufficient in the future. As we endeavor to feed pigs more closely to their requirements, it will become increasing important that techniques are available to determine both nutrient levels and availabilities. The use of near infrared reflectance (NIR) technology or other rapid nutrient analysis methods prior to mixing feed could allow for "real-time" feed formulation and significant reductions in safety margins of nutrients (Ferket et. al., 2002).

Assessing Phosphorus Availability. For determining the availability of P in ingredients for swine, two different approaches have been used. One approach, used in the United States is based on a slope-ratio assay in which bone characteristics are related to the inclusion level of the test source of P in the diet (Cromwell, 1993; National Research Council, 1998). Values are compared to a standard source of P, monosodium phosphate. A second approach, used in

The Netherlands and France, is to determine apparent faecal P digestibility in P sources at low levels of P intake (eg. Jongbloed, 1987; CVB, 1998; Jongbloed et. al., 1999). There is some general agreement for most feed ingredients between the two methods. However, differences are apparent for some ingredients, such as canola meal, dehulled soybean meal and dicalcium phosphate and raises concerns about the adequacy of these approaches to estimate P availability and within ingredient variability in P availability. In The Netherlands, the use of digestibility values has lead to an increase in the use of monocalcium phosphate, rather than dicalcium phosphate, as the mineral source of choice in pig diets. At the University of Guelph, Dr. Fan is leading a research project to determine true phosphorus digestibility in pig feed ingredients (Fan et. al., 2001), which is a further refinement of the apparent digestibility assay used in The Netherlands and France.

Table 3. Bioavailability of nitrogen and phosphorus in feed ingredients for pigs (National Research Council, 1998).

Feedstuff	Bioavailability		Feedstuff	Bioavailability	
	P* (%)	N** (%)		P* (%)	N** (%)
Cereal Grains			High Protein Meals - Plant		
Corn	14	78	Canola meal	21	78
Oats	22	76	Soybean meal, dehulled	23	90
Barley	30	79	Soybean meal , 44% protein	31	89
Triticale	46	81			
Wheat	50	81	High Protein Meals - Animal		
			Feather meal	31	67
Grain By-products			Meat and bone meal	90	80
Oat groats	13	79	Dried skim milk	91	93
Corn gluten meal	15	80	Blood meal	92	94
Rice bran	25	78	Fish meal	94	95
Wheat bran	29	71	Dried whey	97	87
Brewers grains	34	82			
Wheat middlings	41	89	Inorganic Phosphates		
Corn gluten feed	59	66	Steamed bone meal	85	-
Distillers grains	77	75	Defluorinated phosphate	90	-
			Monocalcium phosphate	100	-
Miscellaneous			Dicalcium phosphate	100	-
Alfalfa meal	100	56			

* relative to the availability of P in monosodium/monocalcium phosphate which equal 100
**true ileal digestibility of lysine

Feed ingredients vary considerably in their nutrient content across ingredients and also within a single feed ingredient. When researchers at the University of Guelph analyzed the P and phytate levels in Ontario corn and soybeans they found large differences depending on variety, location, and growing conditions (Leech and de Lange, 2002a,b). In corn, total P content ranged from 0.22% to 0.42% while phytate levels varied from 48% to 90% of total P. In soybeans, total P levels varied from 0.36% to 0.84% with the percent as phytate from 43%

to 71%. Unfortunately, at the present time, there is no quick commercially available method to routinely determine phytate levels.

Assessing Amino Acid Availability. As we feed pigs more closely to their requirements, it will become increasingly important that the amino acid availabilities in feed ingredients are accurately determined. This applies in particular to lysine, which is generally the first limiting amino acid in pig diets. It is generally accepted that the ileal amino acid digestibility assay provides reasonable estimates of amino acid availability in the various ingredients (Table 3). However, in heat-treated protein sources, or in ingredients containing large quantities of anti-nutritional factors, the ileal digestibility assay may over-estimate amino acid availability. Novel techniques are being developed to routinely estimate amino acid availability in feed ingredients (Moughan and Rutherfurd, 1996).

Match Supply of Available Nutrients to Requirements

The key to minimizing nutrient output is by feeding animals according to their nutrient requirements. Over- or underfeeding nutrients relative to the animal's requirement will increase output since animals will simply excrete all of the nutrients they are unable to use for maintenance and growth. Accurate estimates of nutrient requirements are essential to optimize the production system but they are a moving target, depending on factors such as energy density of the diet, stage of development, genetic potential, sex, environmental temperature, and health status. Since nutrient requirements and the optimum dietary nutrient levels differ between individual pig units, the main determinants of nutrient requirements may be monitored on individual pig units. In grower-finisher pigs, estimates of feed intake and lean tissue growth will provide good information for nutritionists to establish target diet nutrient levels (de Lange et. al., 2001).

Phase Feeding. As the liveweight of a pig increases from 30 to 110 kg, the optimum concentration of amino acids and P in the feed decreases. So, the introduction of one or more additional feed(s) for grower-finisher pigs will help balance amino acids and digestible P in the diet to the requirements of the animal so less N and P is excreted (Figure 1). When diets are precisely formulated to meet the protein and amino acid requirements of pigs, N excretion is reduced due to decreased dietary excess and improved utilization of nutrients. Calculations show that by changing from one feed system that is common in Ontario to a 2-phase system, the N needs would be met more precisely resulting in a reduction in N in manure of 12% (Table 4). Going from a 1-phase to a 3-phase feeding program should reduce N excretion by about 17.5% (van Kempen and van Heugten, 2001). Clearly, the incremental benefit of implementing one additional diet in a phase feeding program is smaller as the number of diets in the phase feeding program is increased.

A slightly larger reduction in N and P excretion can be achieved for growing pigs by mixing a feed rich in protein and minerals with a feed that has a low concentration of protein and minerals in a changing ratio during the growing period. This mixing system, referred to as multiphase feeding, works with a computerized mechanical feeding system. A feeding strategy is developed once a good fit of energy, protein, and mineral supply has been established based on pig potential, stage of production, production objective and environmental constraints (Jongbloed and Henkens, 1996).

Figure 1. Effect of number of feed phases on nutrient excess relative to nutrient requirement.

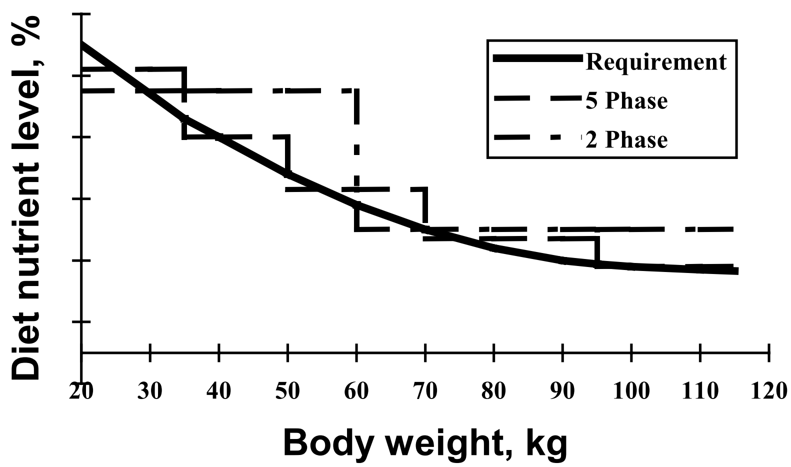

Table 4. The effect of phase feeding on nitrogen excretion in grower-finisher pigs.

Item	One Feed	--------- Two Feeds ---------		
		Grower	Finisher	Overall
Protein (%)	16	16.5	14	14.88
Feed:gain	2.85			2.82
Feed intake (kg)	257	89	165	254
N intake (kg)	6.57	2.35	3.70	6.05
N retention (kg)	2.3			2.3
N excreted (kg)	4.27			3.75
N excreted (%)	65			62
% improvement				12

Split-Sex Feeding. Feeding barrows and gilts separately can also decrease excretion of N and P. It is well known that barrows eat more feed, grow faster, are less feed efficient and yield lower carcass lean than gilts. Although there is little difference between barrows and gilts up to 25 kg, differences in feed intake and growth rate may be as high as 15% during the finisher phase. Because they eat less feed and have a higher lean growth rate, gilts require higher levels of amino acids and other nutrients than barrows. Different diets can be fed to more closely match the nutrient requirements of the separate sexes while limiting excesses and reducing excretion.

Replace Protein with Synthetic Amino Acids

Protein is an expensive nutrient in pig diets, so maximizing the efficiency of protein and amino acid utilization is important. Diets containing amino acids at minimum requirement (for maximum lean growth) with minimal excesses is critical. An experiment using chemically defined diets containing amino acids as a sole source of dietary N, showed that, with a near perfect amino acid balance, a 15 kg pig is capable of converting 87% of its absorbed N above maintenance to body protein. This does not mean that each of the 23 amino acids found in dietary protein are used at 87% efficiency for protein (some are used more efficiently, others less). Ideal ratios of essential amino acids to lysine have been proposed, suggesting an "ideal protein" that corresponds to the pig's requirement (Table 5).

Feed ingredients are combined to meet the pig's requirements for the most limiting amino acid. As a result, the protein content of the diet is higher than required because of the presence of excess amino acids. For grower-finisher pigs, the greatest improvements in the efficiency of N utilization can be achieved from improving the dietary amino acid balance, so that the diet more closely reflects the true balance in which amino acids are required. Through manipulation of the dietary amino acid balance, N excretion in manure can be substantially reduced, by 35% in grower pigs and 20% in finisher pigs, without affecting animal performance (Tuitoek et. al. 1997). In a simple example, N excretion can be decreased by approximately 15% when a 16% protein grower diet is replaced by a 14% protein finisher diet at 60 kg.

Table 5. Ideal amino acids ratios for pigs in four weight ranges, expressed on a true ileal digestible basis (National Research Council, 1998).

	Ideal Ratios (% of lysine)			
Amino Acid	10-20 kg	20-50 kg	50-80 kg	80-120 kg
Lysine	100	100	100	100
Arginine	42	40	36	31
Histidine	32	31	32	31
Isoleucine	54	54	56	56
Leucine	101	100	102	98
Methionine	27	27	27	27
Methionine + Cystine	57	57	59	60
Phenylalanine	60	59	61	60
Phenylalanine + Tyrosine	94	94	95	94
Threonine	62	63	65	65
Tryptophan	18	18	18	19
Valine	68	67	68	67

Synthetic amino acids are commonly added to swine diets. L-Lysine-HCL is the most commonly used, and DL-methionine is used in some diets. Recently, synthetic L-threonine and L-tryptophan have become commercially available. The ability of the swine industry to efficiently use competitively priced synthetic amino acids is limited by our knowledge of amino acid requirements of pigs and of biological availability of amino acids in feed ingredients (Coffey, 1996). The order in which amino acids become limiting will vary with pig body weight, body protein gain and feeding level. With the current cost of synthetic amino acids, it does not make sense to include synthetic amino acids other than lysine in grower pig diets but this will change as the availability and price of other amino acids improves (de Lange, 2002).

CONCLUSIONS

In many areas of the world the contribution of animal agriculture to environmental pollution has become a serious concern. In some countries this has lead to the introduction of legislation to reduce mineral excretion by farm animals. Through science-based nutritional strategies, the mineral balance on pig farms can be substantially improved. Most of these strategies are quite simple to implement and can have a significant impact on nutrient output (Table 6) and the operation's profitability. The most promising and practical of these strategies focus on two main principles - minimizing input and maximizing the efficiency of utilization. Using phytase, replacing protein with synthetic amino acids, and by feeding more closely to the animal's requirements, N and P excretion in pig manure can be reduced by up to 50%. Application of nutritional strategies to reduce mineral excretion will increase the need for precise feed ingredient evaluation, feed formulation, manufacturing, and delivery. Reducing water wastage from drinkers can also have an impact on manure volumes.

Table 6. Potential impact of nutritional strategies on excretion of nitrogen and phosphorus (van Heugten and van Kempen, 2001; Ferket et. al., 2002).

Strategy Used		Reduction in Nutrient Excretion
Improve feed efficiency	➜	3% for every 0.1 unit in improvement
Minimize feed wastage	➜	1.5% for all nutrients for every 1% reduction
Match nutrient requirements	➜	6-15% for N and P
Phase feeding	➜	5-10% for N and P
Split-sex feeding	➜	5-8% for N
Phytase	➜	2-5% for N; 20-50% for P
Formulate on nutrient availability	➜	10% for N and P
Replace protein with amino acids	➜	9% for N for every 1% reduction in crude protein
Highly digestible feed ingredients	➜	5% for N and P
Pellet the ration	➜	5% for N and P
700-1000 micron particle size	➜	5% for N and P
Enzymes: cellulases, xylanases, etc.	➜	5% for N and P for appropriate diet
Growth promoting feed additives	➜	5% for all nutrients
Low-phytate corn	➜	25-50% for P

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TOWARDS ZERO WASTE SWINE PRODUCTION

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ABSTRACT

A novel swine production system was developed that has the potential to be profitable while substantially reducing waste streams. At the basis of this system is a modified housing system. Instead of mixing urine and feces in a pit, they are collected separately using an inclined conveyor belt placed in the pit. Due to a slope of 4%, urine runs off the belt into a collection gutter, which takes it out of the building into a closed storage container. As a result of separating urine and feces, ammonia and odor emission from the house is substantially reduced. Urine collected can be used as a fertilizer, its nitrogen can be converted to harmless N_2 gas, or it can be recovered through chemisorption for use as a pure fertilizer. Feces are passively dried while on the belt, and can be harvested daily at 6 a.m. with a dry matter of approximately 50%. Dried feces can be used as an energy source, for example in a gasifier. Simple gasifiers seem to be the best fit for the industry, although these units have a limited range of end products, including heat, steam, or electricity when implemented on a large scale. Ash remaining after gasification is a good source of minerals for swine feed, but can also be used as a fertilizer or concrete amendment. The economics of the system depend strongly on the value of the energy produced; where other (expensive) energy sources can be replaced it is a viable alternative. In summary, the RE-Cycle system addresses environmental concerns that face the swine industry while generating a green energy supply.

INTRODUCTION

The production of manure is invariably a consequence of swine production. Historically, this material was used as a valuable fertilizer for crop production. However, intensification of swine production and the geographical separation between crop and swine production has resulted in difficulties applying manure to cropland as a fertilizer. As a result, manure is sometimes treated as a waste product.

Swine manure contains several compounds that, when not managed properly, can lead to pollution. Nitrogen has received a large amount of attention as it can affect water, soil, and air quality. Nitrogen is excreted in urine predominantly in the form of urea, and in feces predominantly in the form of protein. Urea is easily degraded into ammonia, which can volatilize and result in air pollution. Most nitrogen remaining in the manure is highly soluble, and after application can run off croplands into surface waters or penetrate to ground water reservoirs. Other compounds that are of environmental concern are listed in Table 1.

In order to solve the environmental challenges facing the swine industry, it is important that systems are developed that minimize the production of compounds of concern, or that produce value-added products in which these compounds are utilized in a sustainable matter. Table 1 can provide some guidance for this, as it lists the sources of several of these compounds. Thus, it provides insight into what a system needs to accomplish to be maximally sustainable. For example, odor is mainly derived from animal housing, while a substantial portion of ammonia and methane is from the animal housing. Thus, sustainable production systems need to start modifications in the house.

Table 1. Sources of compounds of concern at a typical swine farm, and effectiveness of treatment systems to deal with this compound. (0=not treated, +=partially treated, ++=fully treated)

	Main source	Digester	Bioreactor	RE-Cycle
Nitrogen	Urine, feces	0	+	++
Phosphorus	Feces	0[a]	0[a]	++
Copper, zinc	Feces	0	0	++
Organics	Feces	+	+	++
Odor	Swine housing	0	0	+
Odor	Manure	++	++	++
Ammonia	Swine housing	0	0	+
Methane	Swine housing	0	0	0
Methane	Manure storage	++	+	++
Microbes	Feces	+	+	++
Bio-active compounds	Feces	+	+	++

[a] Phosphorus is concentrated in microbial mass, which can be harvested as sludge.

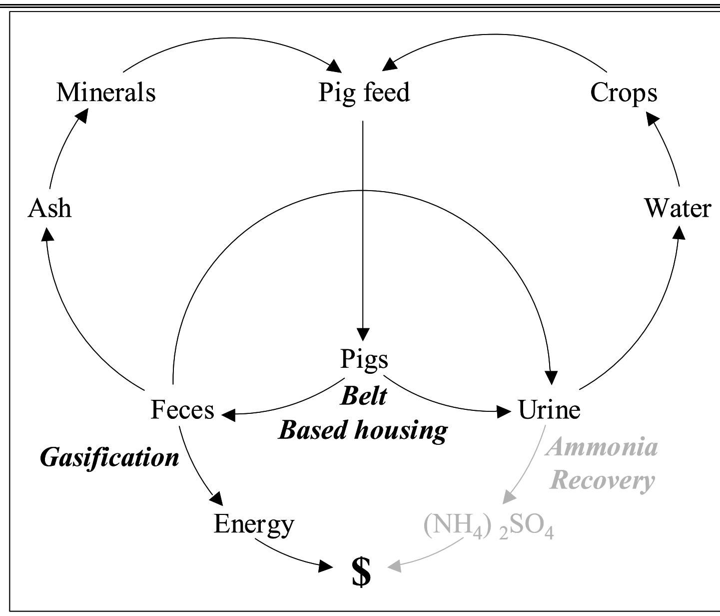
Thus far, most research projects with as objective a sustainable production system have focused on a specific problem and typically they have started with the waste as it comes out the swine house. This means that odor, ammonia, and methane from the house are not addressed. It also means that the starting material had a given composition; swine manure with a dry matter content of less than 10%, limiting what can be done with the material. Examples of such systems include digesters that focus on recovering energy from biomass, and bioreactors that focus on conversion of nitrogen into harmless nitrogen gas.

Although these systems are effective given their objectives, they do not address the range of concerns that face the animal industry. For example, a digester can produce methane for use as an energy source, but the total volume of waste as well as its nitrogen and phosphorus content is not changed. Thus, the need for land application or further processing of the waste has not changed, making this a method to recover value from manure but not for improving sustainability. Worse, the manure has actually lost fertilizer value as organics have been reduced. Bioreactors that convert nitrogen into nitrogen gas are even more challenging. First, they derive no value-added compounds and thus only constitute a cost for the farm. Second, they do not affect waste volume and leave phosphorus and other minerals in the waste, making land application of the residual much more problematic than for the original manure as it now has lost fertilizer value for N.

The RE-Cycle system was designed with the objectives of recycling or prevention of waste without negative effects on the profitability of an operation. From Table 1 it follows that we had to start with modifying the swine housing system to address all the issues that we were facing. The change made in the housing system is actually pretty simple: urine and feces are *collected separately*. This can be achieved with a fairly simple belt collection system that is placed in existing manure pits. Such a system prevents the mixing of urine and feces, which results in a major reduction in ammonia and odor emission. The resulting waste streams, urine and partially dried feces, each have unique attributes. Feces can be passively dried and used as an energy source, leaving only minerals as a co-product. These minerals can be used as an animal feed, fertilizer, or building product. Urine can be denitrified, the nitrogen can be extracted, or it can be used as a fertilizer.

Schematic overviews of the RE-Cycle system are shown in Figure 1 and Figure 2, and a more detailed description of the modified housing system and processing of feces is provided below.

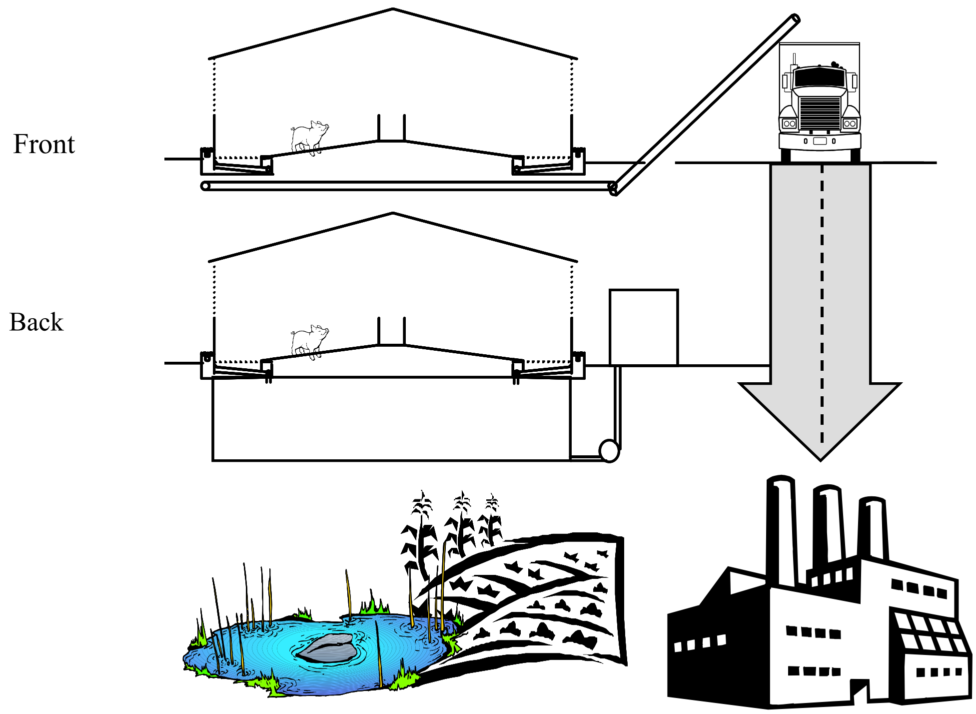
Figure 1. Fate of nutrients in the RE-Cycle system.



CONVEYOR-BELT BASED SWINE HOUSING

Conveyor belts have been used in the laying hen industry for approximately 30 years with good success. They require minimal intervention, last 8 to 10 years, and allow the poultry manure to be collected in a dry form with minimal ammonia and odor emission. The major challenge with pigs is that pigs produce a large volume of urine, which has to be separated from the feces. To achieve this, the belt should be placed at an angle so that the urine runs away from the feces.

Figure 2. **Overview of the RE-Cycle system. Top: Swine feces are collected on a belt system placed in the barn and are harvested in a dry state. These feces are transported to a gasification plant where they are used as an energy source. Bottom: Urine is continuously removed from the building by gravity. Urine is either used as a fertilizer, treated on farm to convert the nitrogen to N_2 gas, or it is processed through a system that can recover the nitrogen in usable form. Remaining water is used for irrigation.**



Typical behavior of pigs is to defecate against the back walls of pens or against open partitions between pens, and this behavior can be utilized in constructing a belt-based housing system. Using a partially slatted housing system as a starting point, belts that cover the width of the flush-gutter are placed in the existing flush-gutter such that the highest end of the belt is against the back wall, sloping inward at approximately 4° (Figure 3). At the low end of the belt, a gutter is installed below the belt or the belt is bent back upwards to generate a urine gutter. The advantage of a separate gutter is that ammonia emission can be maximally reduced as this gutter can be covered, but the disadvantage is that solids (especially spilled feed) can settle in the gutter leading to clogs and odor. The advantage of the gutter integrated in the belt is that the gutter is cleaned whenever the belt operates. However, the gutter residue can lower the dry matter content of the feces collected and the exposed urine in the gutter can augment ammonia emission.

For an optimal air quality in the swine barn, it is paramount that the urine be removed from the barn as soon as possible. This is because fecal contamination of urine results in the breakdown of urea to form ammonia, which can volatize. Ammonia has a negative effect on animal and worker health and well-being and has been implicated in eutrophication (nutrient enrichment of the environment). In buildings that are placed on a slope and that use the above belt design, the urine continuously flows out of the building. Research has shown reductions in ammonia of 65 to 80% depending on the extent of pen fouling. Actual ammonia concentrations measured in a facility with a ventilation rate of approximately 50 m^3/h/pig place were 2-3 ppm. Total ammonia emission was found to be equivalent to 6.5±0.6% of the feed nitrogen (Table 2).

Figure 3. **Belt setup in a conventional, partially slatted, swine house. A polypropylene belt is placed at a 4° angle in the pit such that urine runs off into a gutter, while feces stay on the belt and dry passively. Feces are collected daily at 6 am at a dry matter content of approximately 50%. Benefits of separating urine and feces are a dry fecal waste stream and substantially reduced ammonia and odor emission.**

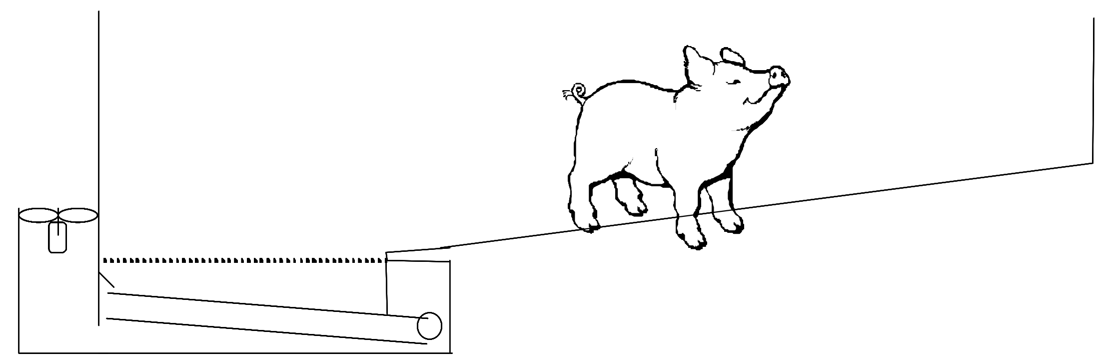


Table 2. **Summary of animal and environmental performance data obtained with the belt housing system over five trials.**

Pigs per trial	80 to 100
Weight range, kg	25 to 55
Average daily gain, kg	0.84±0.08
Average daily feed intake, kg	1.67±0.20
Gain to feed	0.50±0.01
Water intake, l/d	4.1±0.5
Urine collected, l/d	1.3±0.2
Feces collected, kg DM/d	0.26±0.05
Feces dry matter, %	48±6.3
Ammonia emission, kg/year/pigplace	1.23±0.10
Methane emission, kg/year/pigplace	1.05±0.29

Possibly because of the lower ammonia levels in the building, excellent animal performance was observed. Gain to feed for five groups of pigs raised from 25 to 55 kg averaged 0.50±0.01, a 5 to 10% improvement over the gain to feed observed of similar pigs in commercial buildings. Another benefit of removing urine from the building is a marked reduction in odor as odor is linked to aging urine. The urine that is collected contains only minimal contamination from fecal material, as judged by appearance and mineral composition.

Methane emission was equivalent to 0.41±0.13% of the feed energy intake. Data from this and other trials in our lab show that methane emission from the building is mainly derived from the animal (through flatulence and possibly through respiration). Reducing this source of methane emission is possible through dietary manipulations. The manure itself, unless stored in a deep pit, does not seem to contribute to methane emission.

To harvest the feces with the highest dry matter content possible, it was originally believed that the residence time on the belt was of importance. The longer the feces sat on the belt, the more time it had to dry. This assumption turned out to be false. After a day, feces accumulate on the belt to a point that urine does not run through freely, trapping the urine and creating puddles. What was observed, however, was that the time of collection was of major importance. Feces collected late in the afternoon were the wettest; those collected early in the morning, the driest. The reason for this is that pigs are asleep most of the night and thus do not urinate, allowing the feces to dry. During the day, the pigs' urination decreases the dry matter content of the feces. Harvesting feces at 6 am has proven very effective, with dry matters averaging 48±6.3%. At this point the feces are dry to the touch, don't clump, and are stable when stored. In a commercial setting, these feces can be conveyed to a truck bed for collection or to a composting shed.

The equivalent of 17.5±2.1% of the dry matter feed intake was recovered as fecal dry matter. This value is in good agreement with the dry matter digestibility of a typical corn soybean meal diet, suggesting that feces were completely recovered with the belt. This fecal material, on a dry matter basis, has an energy content of 19.7 kJ/g, and contains 45% carbon and 12% ash. These values make it well suited as a fuel when harvested dry.

As wet-dry feeders are used that minimize water wastage, and as the entire system has been set up to stimulate evaporation, the equivalent of only 33±6.3% of the water intake is recovered as urine. Total waste production with the belt is less than 2 kg per animal per day, substantially less than in conventional facilities. This difference is believed to be related to reduced drinking water waste, and increased evaporation of water from the waste streams.

The costs of retrofitting existing barns with a belt are estimated at US $7 to $8 per pig place per year. This is based on individual farms with 4 barns each holding 1200 pigs and includes the costs of urine processing (using a sequential batch reactor) and feces storage. This cost picture does not take into consideration any improvement in animal health and performance that may occur. It also does not take into consideration that waste disposal, under current conditions, has a cost associated with it that can be avoided.

GASIFICATION

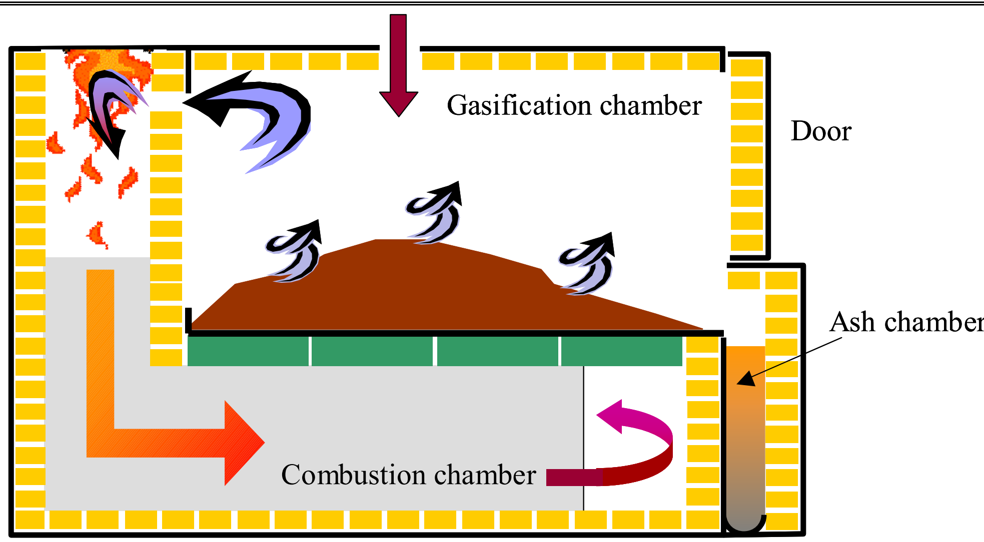
Gasification is a form of thermal decomposition in an environment with limited or no oxygen. The concept is that material is indirectly heated to very high temperatures, for example, 800°C, at which point organic material decomposes into gases such as H_2, CO, CO_2, CH_4, and ash containing minerals. These flammable gasses can then be used as an energy source or as chemical building blocks for the production of value-added compounds such as ethanol.
Gasifier designs range from very simple, where heat is the main end product, to complicated systems with high-value end products such as ethanol or diesel. Initially, for the RE-Cycle project, a very complicated gasifier was evaluated that was designed for the production of liquid fuels. The liquid fuel we were focusing on was ethanol, for which we thought commercially viable catalysts were a reality. The complexity of the gasifier, however, turned out to be a major stumbling block, requiring highly trained people for running the equipment. Even then down-time as a result of system failure was substantial. Similarly, the catalysts for the production of ethanol (and diesel) currently available still suffer from poor efficiencies and they result in the production of byproducts, which would require clean-up processes or further processing of end materials. Although this technology holds promise, our evaluation suggests that neither the complicated gasifiers nor the catalysts for converting product gas into liquid fuels are ready for commercial application in animal agriculture.

As an alternative, BGP Inc. of Scarborough, Ontario, provided a much simpler gasifier. The design of this gasifier is based on years of experience, with the primary objective being the destruction of waste without causing air pollution. The original design contained no moving parts other than a door for loading and unloading, and a downdraft blower. However, to better fit this technology into animal agriculture the unit is being re-engineered to allow for simple but automatic loading and unloading of the unit, thus allowing for unattended processing of waste. A diagram of the re-engineered unit is provided in Figure 4.

Experiments with a non-automated version of the BGP gasifier have shown that the unit is indeed easy to operate and that it operates fail-safe. Batches of manure can be gasified in approximately 4 hours. Ash remaining is of high quality (see next section). However, the unit upon delivery contained an oversized burner. Even at a low setting, the size of this burner caused an escalation of the gasifier temperature when combustible gasses were formed from the fecal material. In addition, the current unit has not been designed to recycle energy in order to minimize fuel consumption. This could be achieved with a relatively simple heat exchanger. Realistic fuel consumption data, however, could not be determined. Extrapolating from current data it is estimated that the fuel consumption is such that for each unit of fuel energy three units of heat are produced, two of them derived from the feedstock. How far this can be improved by optimizing the design of the gasifier is not currently known.

Using such a system on a farm with 5,000 grow/finish pigs would result in a total heat output of approximately 0.55 MW. A portion of this heat can be harvested in the form of hot water, or it can be converted to electricity. The latter, although technically possible, is not the best solution as such systems increase in efficiency with size, with an on-farm system probably not being economical. Using the heat as hot water would allow for heating of buildings, which can result in cost savings. Other uses of heat may exist as well. One possibility is to use it to evaporate water from the liquid waste stream to concentrate it such that the remainder can be used as a concentrated fertilizer.

Figure 4. **Schematic diagram of the gasifier. A downdraft burner is used to heat the L-shaped combustion chamber to, eg., 800°C. Heat transfers from the combustion chamber into the gasification chamber through heat-conducting tiles (the rest of the unit is lined with insulating fire-bricks). Feces are introduced in batches into the gasification chamber through a hatch located on the top of the unit. Inside, the feces are heated up causing the material to gasify. Gasses formed during this process escape from the gasification chamber into the combustion chamber, where they are burned and fuel the system. Ashes remaining after gasification of the feces are dumped using a tilting floor in the gasification chamber into an ash chamber, where any carbon remaining is burned off. Ash is removed from the bottom of the ash chamber using an auger.**

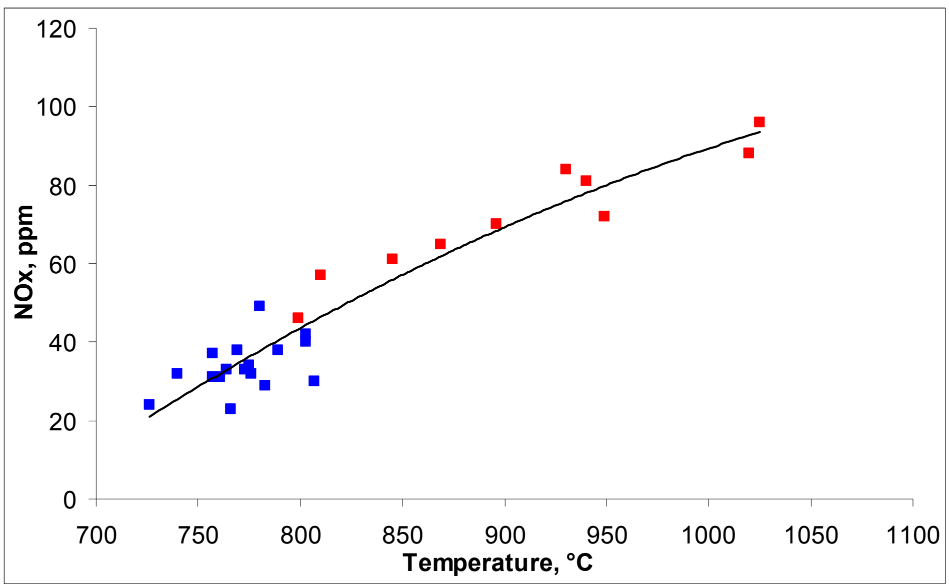


Another possibility is to gasify the feces in a central location such that much larger scale operations can be built. In that case, heat could be used more efficiently for electricity production. If a profitable market for electricity does not exist, then the heat could be used for the production of steam for a feed mill or rendering plant.

Utilization of the heat generated remains a major challenge in practice given that electricity production with the intent to sell is not economically attractive without a form of green energy credits. An 'outside the box' concept would be to use the heat as an energy source for a process that requires a large amount of heat. Ideally such a process would be relatively simple, would result in products that are easy to market, and would be profitable. Some ideas include the production of bricks and glass. Production of a nitrogen fertilizer is an intriguing but likely controversial prospect. Nitrogen could be harvested from the air using the Haber-Bosch process, a process that otherwise only consumes energy. So far the most appealing idea is to use the heat for the production of cement. Cement is made by exposing limestone to very high temperatures, followed by some grinding and mixing. Overall, this process is relatively simple, limestone is a ubiquitous resource, and marketing cement should not be a major challenge.

One of the reasons that gasification technology is appealing is that it is deemed more environmentally friendly than regular combustion processes. Although gasification is a combustion process, during gasification both temperature and oxygen availability can be controlled. This control is responsible for the lower levels of pollutants. For example, dioxins are formed at temperatures well above 1000°C. NOx emissions are also temperature dependent (Figure 5), with production becoming pronounced at temperatures over 700°C and becoming of concern over 1000°C.

Figure 5. NOx emissions observed during the gasification of swine feces as a function of the operating conditions of the gasifier. NOx emissions increased with increasing temperature. However, all temperatures tested resulted in NOx emissions below EPA emission guidelines.



One major benefit of gasification of fecal material is that any bioactive compound in it is destroyed. This would include antibiotic residues, bacteria, viruses, and prions. Although there is little proof at this point that any of these form a real concern for public health, such destruction would be welcomed by the general public.

RECYCLING OF ASH

Using grower feed as a starting point, approximately 17.5% of the dry feed mass is converted to dry swine feces. Upon gasification, approximately 12% of the fecal mass is converted to ash. Thus, per kg of grower feed 20 grams of ash is produced, or 2%. This ash contains most of the minerals that were in the swine feces in either oxide or carbonate form. The ash (composition in parenthesis) is rich in elements such as Ca (11.5%), P (13.3%), and Mg (5.8%) as these minerals are predominantly excreted in the feces. The ash recovered from the gasifier has been exposed to temperatures of 800°C and is thus sterile. Therefore, from a disease perspective it is perfectly safe to feed this ash back to pigs.

The mineral digestibility of the ash has been evaluated both in pigs and under lab conditions. Results of both assays were in agreement and showed that the digestibility of minerals in ash was practically equivalent to the mineral digestibility in commercial sources of these minerals (for example, limestone and dicalcium phosphate). This means that the ash becomes a value-added product in the RE-Cycle system.

Formulating a diet based on this ash composition showed that, for grower pigs, the inclusion in the diet of 2% ash (treated with hydrochloric acid to reduce the pH and provide chloride), 0.15% salt, and 0.6% limestone provided all the macro and micro minerals needed by the pig. At this inclusion rate, a nearly perfect balance exists between ash production and ash utilization. Other uses for the ash exist as well, for example, as a fertilizer and liming agent (providing Ca and P), or as a concrete amendment. Thus, minerals remaining after gasification can be easily used as a value-added product.

RECYCLING OF NITROGEN

Pigs excrete approximately 50 to 70% of waste nitrogen in urine, mainly in the form of urea. It is this urea that is broken down quickly to result in ammonia emission in conventional swine housing systems. By minimizing contact between the urine and the feces and by removing the urine from the house as soon as possible, ammonia emission can be prevented.

This urine is a good source of nitrogen fertilizer, but as collected it is rather dilute (1% N, approximately 4% solids), unstable, and smelly (after short-term storage), making land application not an ideal solution except when using an injection system under dry weather conditions. Ideally, a method for concentrating and stabilizing urine is developed which would yield a product well suited for fertilization purposes. Possibly, waste heat from an on-site gasifier can be used for this purpose. An alternative method for managing the nitrogen is to nitrify/denitrify it, as is done in many municipal waste-treatment plants. In such a system bacteria first oxidize the ammonia to form nitrates, and then, in a second step, reduce the nitrate to N_2 gas. Nitrogen gas makes up 80% of the atmosphere and can be safely released. Although technically a good option, this process does not produce any value-added products and results in the loss of a valuable resource, fertilizer N. Examples of such systems are sequential batch reactors or constructed wetlands.

An alternative solution is to trap the ammonia from urine using, for example, a reversible chemisorption system such as the Ammonia Recovery Process or ARP. This ARP consists of a column containing a zinc-based resin that reversibly binds ammonia. When urine passes through this column, nearly all of the ammonia (up to 99.7%) binds to the column, and the remaining 'urine' can be used as irrigation water since it is virtually free of nitrogen and phosphorus. Ammonia that is bound to the column is periodically removed by flushing the column with a strong acid solution. The resulting solution of zinc-ammonium-sulfate is transported to a centralized processing facility and converted to, eg., ammonium sulfate or anhydrous ammonia fertilizer. The economics of this process, however, are unknown, and the utilization of urine remains a challenge for the RE-Cycle system.

CONCLUSIONS

Using a belt system for separately harvesting urine and feces provides many advantages. Ammonia and odor emission are substantially reduced, resulting in better air quality both inside (possibly resulting in improved animal performance) and outside the building. Feces can be harvested at 50% dry matter making them suitable as an energy source. They can also be used for the production of compost or for land application as a fertilizer.

Gasification is a possible method for recovering value from the fecal waste stream while destroying all bioactive compounds excreted with the feces. Although it is technically possible to produce high-value products such as ethanol, technical and economical challenges suggest that this is not yet a viable option. Currently available technology allows for the production of heat or steam, and on large scale, electricity. The economics of this system depend on the value of energy that can be realized, something that needs to be investigated for each individual site.

Minerals remaining after gasification are well suited for use as an animal feed ingredient as they contain high levels of calcium and phosphorus, both with excellent digestibility. As alternative, they can be used as a fertilizer or building material.

Urine can be used as a nitrogen fertilizer, or the nitrogen can be removed from it through nitrification/denitrification resulting in a loss of value. Alternatively, the nitrogen can be extracted using chemisorption.

The economics of the entire RE-Cycle system depends on

- the value that can be realized for the end products, especially energy
- the avoided cost for manure disposal using conventional methods
- avoided penalties for exceeding emissions (eg., ammonia)
- the improvements in animal performance.

Combining the different technologies described, the RE-Cycle system has the potential to yield a waste-free, profitable swine production system (see Table 1). The key technology for the system is the belt housing system, as it improves air quality in the house, reduces emissions from the house, and results in waste streams that are much more flexible in their use. Already, commercial houses using this system are being used with good results.

SUGGESTED FURTHER READING

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WHAT MAKES NUTRIENT MANAGEMENT SO CONTROVERSIAL?

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INTRODUCTION

Until recently, nutrient management activities in Ontario were primarily regulated by a complex array of laws and policies, with many gaps and overlaps, supported by provincial and local voluntary farm plan programs. Although these initiatives were positive, the regulatory system did not reflect current and emerging intensive farming practices, or the risks posed to water by new pathogens contained in animal manure such as E. coli O157:H7, the pathogen that contaminated the municipal water supply in Walkerton in May 2000. As a consequence of the events in Walkerton, a plethora of changes to law and policy were initiated, including the enactment in 2002 of: the Nutrient Management Act (NMA), the Sustainable Water and Sewage Systems Act and the Safe Drinking Water Act.

Ontario's NMA and the new general regulation under NMA (O. Reg. 267/03) will have an impact on farmers, municipalities and livestock producers. The regulation took effect on September 30, 2003 and is to be phased in over approximately four years. O. Reg. 267/03 contains 122 sections and incorporates four complex and lengthy protocols. However, its current scope is narrow and it applies to a limited number of existing and most new livestock operations. As one observer has noted, the NMA and O. Reg. 267/03 "are not integrated with existing environmental, planning or municipal legislation." They are "one more irregular piece of Ontario's jigsaw puzzle of regulation," challenging government regulators, farmers, lawyers and others to make the pieces fit and raising complex issues wherever livestock farming is carried on or nutrients are spread on farmland.

This paper traces the history of laws and policy related to nutrient management and describes some of the recent controversies in Ontario.

MANURE AND ENVIRONMENTAL MANAGEMENT

While manure and other bio-solids such as sewage sludge are important sources of nutrients for farm operations, particularly of nitrogen and phosphorus, they can also cause harm to soil, water and air quality and have negative health impacts on humans if they are improperly managed.

As documented in the Environmental Commissioner of Ontario's (ECO) July 2000 special report on intensive farming and groundwater protection and in the ECO 2001/02 Annual Report, pollution from farms is a contributing factor to many of today's ground and surface water contamination problems. Contaminants from agricultural operations can enter surface and/or ground water via runoff from fields, direct deposition by grazing animals, discharge from tile drains, flow through soil and cracks in the bedrock, or improperly sealed or poorly maintained wells. Once contaminated, cleanup of surface water and ground water, in particular, can be expensive and difficult and contaminants can persist in ground water for decades.

Using 1996 data, Statistics Canada estimated that five of the ten areas in Canada that produced the most manure per hectare were in southwestern Ontario. The Maitland, Upper Thames and Grand River areas each produced more than 6,000 kilograms of manure per hectare annually; and the Ausable-Bayfield and Saugeen River areas each produced more than 4,000 kilograms per hectare annually. This is in contrast to an annual average per hectare in Canada of 755 kilograms of manure.

Although materials containing nutrients may improve crop growth, an excess of nutrient materials or inappropriate application of them may not only harm the soil and its crops, but also livestock, humans, wildlife and aquatic ecosystems.

- Excess nitrogen and/or phosphorus can increase the amount of dissolved nutrients in surface water causing algal blooms and long-term ecosystem changes.
- Materials containing nutrients may also contain heavy metals, e.g., cadmium, lead, as well as human and animal pathogens, such as E. coli, Campylobacter, Cryptosporidium and Giardia; hormones and antibiotics; and pesticides.
- Elevated levels of nitrates/nitrogen, in drinking water can cause a rare, but potentially fatal, condition called methaemoglobinemia in babies and has been linked to bladder cancer.

In his Part 2 Report for the Walkerton Inquiry, Commissioner O'Connor stated that "agriculture can be a significant source of the contaminants in drinking water" and that, as part of a multi-barrier approach to providing safe drinking water, the source of the water must be protected. In 1992, 1,292 farm wells were tested in Ontario and 14% were found to exceed Canadian Drinking Water Quality Guidelines for nitrate/nitrite. Increased damage to the environment and human health caused by nitrogen have largely resulted from the intensification of farming practices on a declining land base, resulting in an increased need for more rigorous regulations to mitigate damages. The NMA and O. Reg. 267/03 are premised on the concept that it is essential to mitigate and prevent damage caused by this kind of nutrient overloading.

HOW THE LAW HAS EVOLVED

Prior to Confederation, the common law governed legal liabilities associated with the application of manure to land. The tests applied by courts to determine liability for pollution associated with manure management and spills were related to the reasonableness of the farmer's conduct, the utility of the conduct and whether the discharges to air, water or land related to manure were "natural". During this time lawsuits against farmers related to manure management issues were very rare. However, pathogens such as E. coli O157:H7 had not yet emerged, awareness about environmental problems was low, and the concept of a class action lawsuit had not yet been developed by the legislatures and the courts.

In the late 19th century, the federal government enacted the Fisheries Act (FA), one of the most powerful tools available to the federal government to regulate water pollution. Subsection 36(3) of the FA prohibits the discharge of deleterious substances (which can harm fish) into water frequented by fish unless the deposits are authorized by regulation. Farm operations are subject to this provision as well as the prohibition of activities that "results in the harmful alteration, disruption or destruction of fish or fish habitat" under the FA. However, enforcement against the agricultural sector has been lacking in the past and the Department of Fisheries and Oceans (DFO) or Environment Canada has launched very few prosecutions, although February 2004 reports in Ontario Farmer indicate that this might be changing. The reports describe efforts by DFO and Environment Canada to restrict cattle watering in the streams of Huron County.

In the 1950s, the Ontario government enacted a series of laws that provided the basis for the Ontario Water Resource Act (OWRA). The OWRA is the province's primary piece of water legislation and contains water quality provisions, which allow the Ministry of the Environment (MOE) to protect surface and ground water from pollution and sewage discharges. The OWRA also prohibits "discharges or deposits of material of any kind into a water body or watercourse that may impair water quality." However, these provisions have only rarely been used by MOE in relation to agriculture, chiefly restricted to large manure spills.

In 1971, the Ontario government enacted the Environmental Protection Act (EPA). Provisions of the EPA exempt farmers from being held liable for impairment of the quality of the natural environment if animal wastes were disposed of in accordance with normal farming practices. However, farmers can be charged for the disposal of animal wastes if other adverse damage results, including injury to human health or damage to property or to plant or animal life. Despite this, very few charges have ever been laid and little enforcement action has been taken. Furthermore, the EPA also exempts animal wastes from waste management requirements, such as certificates of approval for generating, hauling and the treatment of wastes, legislation that applies to other waste producers and haulers.

For more than a century Ontario municipalities have had powers under various laws that allow them to try to protect agricultural resources and maintain local environmental quality. In Canada, municipalities have no separate constitutional authority; they are authorized to exercise specific regulatory powers granted to them under provincial laws. Key statutes in Ontario that grant municipalities jurisdiction over environmental and land use matters affecting farm operations include: the Planning Act, the Municipal Act and the Building Code Act. The Planning Act gives municipalities the power to adopt official plans, zoning by-laws and the obligation to regard the conservation of natural resources when considering subdivision approvals.

In 1978, the Ontario government announced its "Food Land Guidelines". The Guidelines required municipalities to identify lands with agricultural potential, to rate them in order of priority and to evaluate the impacts that would be caused by alternative uses of the land. The overall goal of the policy was to encourage municipalities and other decision-makers to protect Class 1 and Class 2 agricultural lands when they made planning decisions. In August 1983, the Planning Act was proclaimed in force, clarifying that planning bodies "shall have regard to" policy statements issued by the Ontario government. In effect, the Ontario government decided to permit the Ontario Municipal Board (OMB) to use its discretion to evaluate the merits of land development and to decide land use planning disputes and conflicts involving agricultural lands.

In the early 1980s, a new wave of urban residents began to migrate to rural areas in many parts of Canada searching for a cleaner environment and a different pace of life. This migration generated increasing conflicts with farmers relating to noise, odours and dust from farms. Eventually, some of these new property owners turned to the courts in the hopes of restricting certain farm activities. In response, provincial and municipal governments across Canada began to look at legislation to protect farmers from these lawsuits.

In 1988, the Ontario government enacted the Farm Practices Protection Act (FPPA). This law was intended to protect farmers from lawsuits launched by neighbours, and required plaintiffs to seek approval of the Farm Practices Protection Board before they could launch a lawsuit. The Farming and Food Production Protection Act, 1998 (FFPPA), replaced the FPPA and strengthened the protection of farmers against lawsuits and complaints from neighbours, legislating in section 6 that farming practices cannot be restricted by municipalities if they are determined to be normal by the Normal Farm Practices Protection Board (NFPPB). Few lawsuits have been approved by the NFPPB in the intervening 15 years; to our knowledge there has not been a single one. However, over the years Ministry of Agriculture and Food (OMAF) staff and the NFPPB have ruled that a number of farm activities are not normal farming practices and this has created a body of rules as to acceptable practices. Moreover, in one case decided in 1999, Pyke v. TRI GRO, the lawyer representing the plaintiffs did not apply to the NFPPB and successfully sued a mushroom grower. Despite the express provisions of the FFPPA, two of the Court of Appeal Judges allowed the judgement to stand. The NFPPB also has issued a number of decisions on manure management and the ability of municipalities to restrict new farm operations and some of these are reviewed below.

In the early 1980s, the MOE, the Ministry of Natural Resources and other stakeholders became concerned about non-point source water pollution from farms and the closure of beaches on Lake Huron. In 1986, the MOE established a program called Cleaning Up Rural Beaches (CURB), targeted at cleaning up beaches on Lake Huron. This program operated until early 1996.

OMAF and many of its stakeholders (such as the Ontario Federation of Agriculture) have long promoted a voluntary approach to nutrient management, and spent approximately 15 million federal Green Plan dollars in the early 1990s to support the Environmental Farm Plan Program (EFPP). Since 1993 OMAF has provided technical support to the voluntary EFPP, which encourages farmers to develop Environmental Farm Plans (EFP), including manure management plans. Some excellent work has been done under this program. However, because participation in these projects has been voluntary, the off-farm ecological impacts caused by manure management are not emphasized and data collection on EFPs was uneven, there was no assurance that the program had changed practices on the majority of farms.

In February 1994, the Ontario government enacted the Environmental Bill of Rights (EBR). This law contains a number of new tools, such as the right to request an investigation if an environmental law such as the EPA or the OWRA is being contravened. The EBR also contains new rights to sue polluters; however, the law also requires that plaintiffs first obtain approval of the NFPPB before they can launch a lawsuit against farmers. These provisions were inserted into the EBR at the insistence of the Ontario Federation of Agriculture and other OMAF stakeholders in 1993. To date, only a handful of lawsuits have been launched using the EBR and no lawsuits relying on the EBR have been launched against farmers.

The EBR also creates the ECO. The ECO has issued eight annual reports and five special reports. In July 2000, the ECO released a special report on groundwater and intensive agriculture. This report helped to spur government action on development of the NMA.

Municipal Powers and By-Laws

In 1996, the Planning Act was amended and the provincial government established a new Provincial Policy Statement (PPS) under the Act. The PPS affirms that prime agricultural areas and normal farm practices will be promoted and protected. The 1996 PPS is currently under review and we expect that a revised version of the PPS will be tabled for public consultation in June 2004.

In 2001, the Ontario government significantly revised the Municipal Act. The new law, which took effect in January 2003, contains a number of provisions to authorize control over specific environmental matters using by-laws. Examples include by-law powers on tree cutting, the adoption of waste management plans and by-laws to curb noise pollution. However, it did not alter municipal powers with respect to regulating farm operations.

One tool that municipalities can use to regulate farm operations is the Building Code Act (BCA). Under the BCA, chief building officials (CBOs) must issue a building permit unless there is a violation of the Act or any other applicable law. In practice, CBOs must make these decisions promptly and applicable law includes municipal by-laws. As noted below, municipalities began to develop site plan controls under the BCA to restrict the siting of new large farms in their boundaries in the late 1990s.

The farming exemptions in the EPA and the FFPPA resulted in a nutrient management regulatory gap that was mainly filled by municipalities starting in the mid 1990s. As of May 2003, there were approximately 84 nutrient management municipal by-laws in place. Some of these by-laws have been challenged in courts and at tribunals like the OMB and the NFPPB (some of the court and tribunal decisions are listed at the end of the paper). In Knip v. the Township of Biddulph, the FPPB (as it then was) decided in 1998 that a by-law which limited the number of livestock units located on a piece of property, is a restriction of normal farm practices. The FPPB also ruled that manure management, using a nutrient management plan, instead of adhering to the ratio of one tillable acre for 1.5 livestock units, is a normal farm practice. In Jansen v. Township of Adelaide-Metcalfe, the NFPPB ruled in 2000 that long-term control of manure did not require a lease for cropping purposes. Another NFPPB decision released in 2000, Embury v. Township of Stone Mills dealt with whether a municipality could require a farmer to own at least 40% of the land on which he spread manure. The NFPPB ruled that a 40% ownership level constituted an improper restriction of normal farm practices, even though it acknowledged that a requirement of long-term control of at least 40% of a land base (e.g. through a lease) for spreading manure may comply with normal farm practice. In a supplementary decision, the NFPPB decided that a municipality could use site plan controls as a means of requiring nutrient management planning and this would not contravene section 6 of the FFPPA as a restriction on normal farm practices.

Rob Waters, the former chair of the FPPB between 1990 and 1996, speculates that these types of NFPPB decisions might have encouraged municipalities to try to use interim by-laws and building code site plan controls to restrict large farms. These NFPPB decisions also provided a body of tribunal rulings that shaped the approach OMAF and MOE used to develop the NMA. Other court and tribunal decisions also played a role in the policy development process. In Ben Gardiner Farms v. West Perth Township, the Township had passed a by-law imposing a cap of 600 livestock units per site. The farmer appealed the by-law to the OMB and the OMB initially decided in favour of the Township. When the OMB decision was challenged at Divisional Court, the judge ruled that the by-law restricted normal farm practice by prohibiting farm operations above a certain size and granted leave to appeal to the farmer.

Municipal powers to regulate the environment were given a major boost in June 2001 when the Supreme Court of Canada ruled in Spraytech v. Town of Hudson, finding that it was within the scope of a local government in Quebec to prohibit the use of nonessential pesticides. After the Spraytech decision was reached, there was concern that a glut of by-laws relating to "environmental concerns" would be passed by municipalities, including more by-laws on manure management. Some feared that these by-laws would further exacerbate what the agricultural community considered an unfair advantage to those operations that are not subject to restrictions. It is unclear if this has happened but, to date, it doesn't appear to have.

In Faux v. Township of Havelock-Belmont-Methuen, the issue was whether an interim control by-law freezing the development of intensive livestock operations would restrict normal farm practices. Prior to the NFPPB hearing in February 2002, the Minister of Agriculture, Food and Rural Affairs issued a directive under s. 9(1) of the FFPPA stating that "…a proposal for an agricultural operation shall be deemed not to be carried on as a normal farm practice until a by-law providing for nutrient management planning, minimum distance separation and manure storage has been passed". This provided municipalities with breathing room, allowing them to regulate new operations, and might have been a tip of the hat to the Spraytech decision. However, this directive has now been superceded by provisions in O. Reg. 267/03.

In summary, the proliferation of nutrient management by-laws has been attacked on the basis that they restrict normal farm practices and are an unfair advantage to operations that are not subject to them. Moreover, farming operations that span more than one municipality may be subject to different by-laws leading to confusion about which requirements apply. This was one of the main reasons why the Ontario government felt compelled to develop a clear regulatory system under the NMA. It is expected that, over time, most of these by-laws will be replaced by NMA regulations such that agricultural operations would no longer be subject to differing standards across the province.

The Impact of the Nutrient Management Act

The NMA was given Royal Assent in June 2002 with the purpose to establish province-wide standards to regulate farm practices relating to nutrient management. The purpose of the NMA is "to provide for the management of materials containing nutrients in ways that will enhance protection of the natural environment and provide a sustainable future for agricultural operations and rural development."

Agricultural operations have been defined in the NMA as the growing of livestock, production of crops, and operations such as aquaculture, horticulture and silviculture. It specifically includes activities such as: the cultivation of greenhouse crops, nursery stock and tobacco; aquaculture; the production of maple syrup; husbandry of deer, elk, game animals and birds; and the growing of mushrooms, trees and turf grass. The NMA identifies "nutrients" as fertilizers, organic materials, biosolids, compost, manure, septage (i.e., human waste from septic tanks), pulp and paper sludge, and other material applied to land for the purpose of improving the growing of agricultural crops.

Each agricultural operation will be classified into one of nine categories based on the nature of the operation and on the amount of nutrients generated and received. The agricultural operation would then be required to comply with the regulations specific to its category - intensive farming operations will be expected to comply with more stringent regulations than small, family farms.

Over 26 specific subject matters may be regulated, including:
- The size, capacity, location and construction of buildings that store materials containing nutrients, or house farm animals;
- The amount of materials containing nutrients that may be applied to lands, the quality of the materials, and the type of land to which they may be applied;
- The time and manner in which materials containing nutrients may be applied to lands;
- Preparation, approval and revision of nutrient management plans (NMPs) for agricultural operations, and nutrient management strategies (NMSs) for municipalities and generators of materials containing nutrients;
- Establishment of a registry containing the NMPs and NMSs;
- Collection and chemical analysis of materials containing nutrients;
- Studies of soil type, topography of the land on which the nutrients are to be applied, and of the risk of contamination of water located on, in or under those lands;
- Restricting access of farm animals and persons to lands on which materials containing nutrients have been applied, and to water and watercourses; and

- Establishment of local committees to assist in the management of materials containing nutrients and mediation of disputes.

Under the NMA, any municipal by-law addressing the same topic as a regulation becomes inoperative, thereby establishing uniform province-wide standards.

Under the regulatory system that preceded the NMA, MOE required generators of biosolids (e.g., sewage treatment plants, pulp and paper mills), haulers of septage, and managers of sites onto which biosolids are applied to have and follow certificates of approval under the EPA. In early 2003, OMAF and MOE stated that the current system of approvals for untreated septage would be phased out within five years. Under the NMA, regulations may also require:

- Farmers/applicators of materials containing nutrients to land to pass an examination;
- Persons in the business of applying materials containing nutrients to obtain a license;
- Sites onto which said materials will be applied to have an approved NMP;
- Generators of biosolids to prepare a NMS; and
- Persons preparing or approving NMPs and NMSs to meet designated qualifications.

Similar to the EPA and the OWRA, the NMA provides for the designation of Provincial Officers, who may enter and inspect an agricultural operation without a warrant; and who may issue an order to prevent, decrease or eliminate an adverse effect due to the discharge of materials containing nutrients to the natural environment. Orders may also be issued requiring work to be done or requiring a person to comply with the Act, the regulations, or with their certificate, license or approval. However, unlike the EPA, orders can only be issued to current owners and operators – previous owners and operators are exempt. If an operator fails to comply with the NMA, a MOE official may issue an administrative penalty to a maximum of $10,000 per day for each offence. If the person pays the penalty, the person will not then be charged with an offence.

Operators can appeal decisions regarding the approval/denial of a certificate or a license issued by OMAF, or an administrative penalty to the Environmental Review Tribunal within 15 days.

A corporation convicted of an offence under the NMA may be fined a maximum of $10,000 per day for the first offence, and $25,000 per day for a subsequent offence. However, corporate officers can only be convicted of an offence if they knowingly concur with the commission of the offence. An individual may be fined a maximum of $5,000 per day for the first offence, and $10,000 per day for a subsequent offence. These maximum fines apply to any offence, including offences that result in impairment to the environment.

There is no requirement for farmers to self-report non-compliance with the NMA. In contrast, under the EPA and OWRA, non-compliance must be reported immediately and maximum fines related to impairment of water start at $250,000 per day and rise to $10,000,000 per day. The amount of the fine depends on whether or not an individual or a corporation committed the offence, and whether or not it is a first or subsequent offence. Individuals convicted under the EPA or OWRA may also be imprisoned and corporate officers must exercise reasonable care to prevent the offence from occurring.

Cabinet may delegate functions related to the registry created by this legislation; the review of NMPs and NMSs; and the issuance, amending, suspending or revoking of certificates, licenses and approvals to an individual, partnership or corporation.

NMA also clarifies that compliance with the NMA is to be considered a “normal farm practice” for the purposes of the Farming and Food Production Protection Act. This means that neighbours will not normally be able to sue farmers who comply with the NMA for disturbances such as odour or dust, and must first seek pre-approval from the NFPPB for such a lawsuit.

OMAF and MOE have stated that a central registry of NMPs and NMSs will be created to provide registry users and government with information on sources (generators) and destinations (receivers) of nutrients, and the type, quality and quantity of nutrients generated and applied. This information could then be analyzed to determine volumes and trends, proximity of application sites to watercourses and other sensitive areas, and potential locations for soil and water quality testing. Without this information, it would be difficult for OMAF, MOE and other agencies to assess the impact of the nutrients on watercourses, or to design monitoring programs that can differentiate between agricultural sources and other dischargers, e.g., industry and sewage treatment plants.

In June 2003, O. Reg. 267/03, the first NMA regulation, was filed. The regulation requires building permit applications for establishment and expansion of large livestock operations, regulates manure management on all new farms and many existing farms by 2005, and municipal sewage treatment facilities by 2008.

The regulation introduces two new terms to Ontario agriculture – the farm unit and the nutrient unit (NU). The farm unit defines the agricultural operation in terms of the land that it encompasses. An agricultural operation can be defined as multiple farm units if the conditions in the regulation are met. Each farm unit is required to individually comply with O. Reg. 267/03. For the purpose of this decision review, an agricultural operation is assumed to be one farm unit and will be referred to as a farm.

A nutrient unit is a measure of the size of a farm based on the amount of manure generated or could be generated based on the housing capacity of the farm unit, allowing OMAF, MOE and other stakeholders to compare hog farms with poultry farms. One NU is the amount of manure that gives the fertilizer replacement value of the lower of 43 kg of nitrogen and 55 kg of phosphate. There are four NU thresholds: 300 NU or more, 150 NU or more but less than 300 NU, more than 5 NU but less than 150 NU, and 5 NU or less. The NU threshold determines which rules in O. Reg. 267/03 will apply. There is no restriction in the NMA or O. Reg. 267/03 on the number of animals that a farm can have. This regulation requires new or expanding farms producing over 300 nutrient units (NU) (equivalent to 300 milking Jersey cows, 45,000 laying hens or 1800 finishing pigs) to produce and have approved a NMP and a NMS. New farms producing more then five nutrient units established after September 2003 must submit an approved NMP and NMS when applying for a building permit.

The majority of the rules are being phased in over five years. O. Reg. 267/03 applies first to new livestock farms and existing livestock farms expanding to 300 NU or more, followed by large sewage treatment plants and then existing large agricultural operations. A few rules in the regulation apply to all farms regardless of the NU. An implementation date of 2008 has been proposed for other farms but this matter has been referred to the Provincial Nutrient Advisory Committee for further consideration. Municipal by-laws, if they exist, continue to be applicable to farms not under O. Reg. 267/03.

O. Reg. 267/03 consists of 13 parts including rules on:

- Nutrient management strategies and plans
- Land application standards
- Outdoor confinement areas
- Siting and construction standards
- Sampling, analysis and quality standards
- Application methodology standards
- Licensing and certification
- Monitoring, compliance and enforcement.

The regulation also makes reference to four protocols: Nutrient Management, Construction and Siting, Sampling and Analysis, and Local Advisory Committee which provide additional details and are legally enforceable. The rules described below only apply to farms when they become regulated, i.e., phased-in. It should also be noted that farms with OMAF-approved nutrient management plans developed under an EFP are grandparented for five years until at least 2008.

One of the original objectives of enacting nutrient management legislation was to provide consistent, province-wide rules so that farmers in one municipality are not subject to different rules than farmers in another municipality. Although O. Reg. 267/03 has the potential to fulfil that objective, consistency has not been achieved. Since only large livestock operations, numbering about 1100 according to Statistics Canada Census 2001 data, and new livestock operations or operations expanding to 300 NU or more are covered by the regulation, the majority of the 53,000 farms in Ontario remain subject to municipal bylaws until at least 2008. As noted above, there are currently about 85 municipal by-laws in place. The Provincial Nutrient Management Advisory Committee has been asked to make recommendations to OMAF on whether the remaining 51,900 farms should be brought under O. Reg. 267/03 and, if so, when.

In sum, it appears that approximately 95-98% of current livestock producers will not be subject to O. Reg. 267/03 until 2008 or later. Thus, some commentators have suggested that the NMA will have little effect in the near term on farm practices and environmental damages, although the NMA and O. Reg. 267/03 are important first steps in the development of a comprehensive regulatory system for Ontario.

SOME CONTROVERSIES IN NUTRIENT MANAGEMENT

The Nutrient Management Act is a Compliance and Enforcement Maze

One of the sources of controversy has been described as the nutrient management compliance and enforcement maze created by the NMA. As reported in the ECO's recent annual report, one of the most contentious issues raised by commenters on Bill 81 related to whether OMAF or MOE should be accountable for ongoing enforcement of the NMA and associated regulations. For the most part, agricultural organizations took one of two positions: (a) OMAF should be wholly accountable since the NMA is about nutrient management by farm operations and since OMAF has expertise on farms and a positive, co-operative relationship with farmers; or (b) a MOE inspection unit should be seconded to OMAF. Many farm groups stressed that the approach to compliance and enforcement should be positive and cooperative rather than punitive. For the most part, environmental groups recommended that MOE be wholly accountable for enforcement due to its independence and its expertise in enforcement. In his Part 2 Walkerton Inquiry report, Commissioner O'Connor stated that OMAF may not be sufficiently independent to both promote agriculture and enforce the regulations and he recommended that MOE oversee all compliance requirements of the NMA.

Up until November 2003, it appeared that compliance and enforcement would be multi-layered. OMAF officers would have been responsible for the first line of enforcement. The MOE would only be called in after multiple violations, repeat offences or refusal to admit an OMAF Agricultural Officer. MOE would also have been called in for spills or other incidents that may have a major impact on human health or the environment.

In theory, this plan sounded reasonable; however, the ECO has found that shared responsibilities and limited government resources in the area of Fisheries Act enforcement has sparked jurisdictional turf wars, and can result in "enforcement inertia" and other complications. For this reason, the ECO has argued that it would be logical to assign MOE the lead role in enforcement of the NMA.

The ECO was pleased when Environment Minister Leona Dombrowsky and Agriculture and Food Minister Steve Peters announced in late November 2003 that MOE would be overseeing most compliance requirements of the NMA, consistent with the recommendation of the Walkerton Inquiry report.

Does the Nutrient Management Act Supercede Other Laws?

Section 61 of the NMA states that: "A regulation supersedes a by-law of a municipality or a provision in that by-law if the by-law or provision addresses the same subject matter as the regulation." A provision of a by-law that is superseded will be inoperative so long as the regulation is in force.

Chief Building Officers (CBOs) will have to decide whether a local by-law has been superseded by NMA regulations as explained by one commentator. OMAF has argued that O. Reg. 267/03 will supersede by-laws made under the Planning Act. However, this interpretation is open to question; indeed, section 71 of the Planning Act states that where there is a conflict between the Planning Act authority and other general and special Acts, the Planning Act is paramount. Whether O. Reg. 267/03 supersedes a by-law made pursuant to the Municipal Act will also require interpretation to determine which provisions of the by-law "address the same subject matter" as NMA regulations.

Some legal commentators also argue that unless the legislation is clarified, many of these CBO decisions will be challenged in the courts. For a preview of this kind of litigation, see the City of Ottawa v. City of Ottawa, Chief Building Official, (2003). This decision grants the appellant city a stay of a decision by the city's own CBO to issue a building permit for a livestock farm, pending an appeal to the Ontario Court of Appeal. In December 2003 a Divisional Court panel upheld a ruling that the CBO had to give the producer a building permit, but did not have to designate his newly acquired dairy farm as a legal non-conforming use. The Divisional Court panel of Justices also determined that the trial judge was correct in concluding that a proper interpretation of the term "other applicable law" in the Building Code Act excluded three environmental statutes, the OWRA, the EPA and the Fisheries Act. However, the trial judge did not comment on the applicability of the NMA since the application for the building permit was received before O. Reg. 267/03 came into force.

Funding

A third concern surrounding the NMA is one of funding. In early 2003, OMAF and MOE acknowledged that implementation of the NMA regulations will require training and funding for farmers. Small agricultural operations are expected to need the most assistance. Provincial Officers will also need to be trained in agricultural practices, including biosecurity, to ensure fair and appropriate enforcement and to prevent transmission of disease from farm to farm.

The ECO was delighted to learn in late 2003 that the federal and provincial governments have agreed to renew funding for farm plan work through the Agricultural Policy Framework (APF). One media report in December 2003 suggested that more than $6 million of APF funds would be made available to help farmers comply with the NMA. In May 2004, the Ontario government announced as part of its 2004 Budget that it would provide more than $20 million in funding for work on NMPs.

Public Access to Nutrient Management Plans and Strategies

Since OMAF plans to store NMPs and NMSs in an electronic registry, there is the potential for public access. A number of farming organizations, such as the Dairy Farmers of Ontario, have opposed this access, arguing at the Bill 81 hearings that only “verification of compliance and a short summary of nutrient management plans should be public documents. Full plans should not be available to the public in consideration of sensitive and/or protected information. Plans should be audited by the auditor and not audited by public complaint.” In contrast, the Canadian Environmental Network indicated that NMPs should be public documents so that the public has the opportunity to verify for themselves whether or not agricultural operations are following their plans.

The ECO believes that the proposed central nutrient management (CNM) registry is a critical component and that it should include all NMPs and NMSs. Moreover, the ECO believes that it is essential that much of the data on the new CNM registry be publicly accessible so that decision-making remains transparent and ministries are held accountable for their decisions on NMPs and NMSs. The ECO also recognizes that some of the NMPs and NMSs may contain confidential information and would support allowing farm owners and operators to make requests to MOE and OMAF regarding the validity of posting only summary information on the CNM registry in some cases. The opportunity already exists under MOE policies and procedures for instrument-holders under the EPA and other Ontario environmental laws to make claims under the Freedom of Information and Protection of Privacy Act (FIPPA) to protect confidential information from public viewing. Disputes about these claims are subject to appeal to the Information and Privacy Commissioner. Our view is that the current FIPPA regime could be adapted so that agencies developing watershed plans at a local level would still have access on the CNM registry or on the Internet to descriptions of loadings of nutrients in their watersheds.

Prescribing the Nutrient Management Act under the Environmental Bill of Rights

The ECO is particularly concerned that the NMA may not be subject to the EBR and does not believe that the public concerns regarding water quality will diminish unless the public feels it can participate and the regulatory system is transparent.

The ECO commends OMAF and MOE on the extensive public consultations that took place during the development of Bill 81 and the NMA regulations. The ECO has repeatedly urged OMAF to prescribe the NMA under the Environmental Bill of Rights. If it is not, certain EBR rights may not be available to the public, including applications for review, investigation or leave to appeal, as well as the right to sue for harm to a public resource. In 2002, OMAF indicated that it needed more time to understand the implications of prescribing the Act under most sections of the EBR. In the interim, the ECO urges OMAF to prescribe the NMA under s.16 of the EBR so that the Act's regulations are subject to notice and comment on the Environmental Registry.

The EBR also provides a means for instruments, such as certificates, licenses, orders, NMPs and NMSs to be classified, and posted on the Environmental Registry created by the EBR so that the public can be advised of and participate in decisions on NMSs and NMPs that may affect them. The ECO believes that all instruments related to nutrient management for large agricultural operations should be prescribed under the EBR. This would also include biosolid application sites, which are currently exempt. Again, in order to ensure that public participation opportunities under the EBR are maximized, it would be important to provide adequate information about proposed instruments on the Registry.

CONCLUSIONS

The intensification of farming practices can result in considerable environmental damage, damage that must be mitigated and prevented. Despite the controversy surrounding the NMA and O. Reg. 267/03, they are important first steps as we begin the journey of developing a coherent system for managing nutrients in Ontario and filling in the pre-Walkerton tragedy gap in law and policy.

The authors gratefully acknowledge that some of the material in this paper was originally prepared by Bev Edwards, Policy and Decision Analyst, for the 2002-03 ECO Annual Report.

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THE BOTTOM LINE

COST OF PRODUCTION ON ONTARIO SWINE FARMS

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ABSTRACT

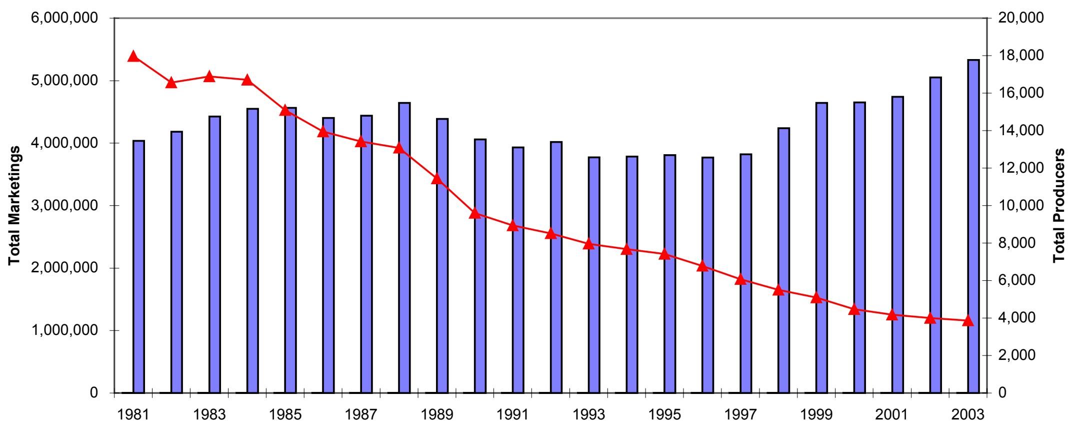
The Ontario Data Analysis Project is used to investigate historical cost of production on farrow-to-finish farms. Unsurprisingly, profitability on a per pig basis shows considerable variability between farms and tends to follow market prices. It is not simply one factor but rather a combination of many factors that contribute to the level of profitability on these farms. The ability to control costs and keep productivity high are two key variables. Other factors include the health, genetics, feed, and management of each herd.

BACKGROUND

Cost of production is often touted as the most important factor in a region's competitiveness within the global pork market. However, it must be recognized that many other factors can influence a jurisdiction's competitiveness and some of these include: exchange rate; government policy; business climate (eg. labour supply); domestic demand; product differentiation and quality; and social factors (eg. receptiveness to corporate hog farming and pork processing). Perhaps one of the better ways to look at a region's competitiveness is to simply look at pig numbers over time. Has the area been growing, stable or shrinking? Ontario has been exceptionally resilient in pork production despite the yearly fluctuations in pig prices and input costs. This is depicted in Figure 1 that shows yearly hog marketings from 1981 to 2003. Notice that 1988 and 1999 hog marketings are similar despite the plummeting producer numbers over the same period.

To investigate Ontario's cost of production for raising market hogs the Ontario Data Analysis Project (ODAP) can be used. This data set contains farm level financial and production information from a group of Ontario farrow-to-finish farms. These farmers consider themselves to be full-time farmers and they report little, if any, off-farm income. Most of the farms rely on family labour to fill additional labour needs. For the 2002 tax year, the most recently available information, there were 15 participants. The average age of the main decision maker was 48 years. Slightly over one-half (i.e. 53%) of the farms were operated as family corporations and 27% were spousal partnerships leaving 13% as sole proprietors. It should be noted that farrow-to-finish farms account for about 60% of the market hogs raised in the province (source: producer survey Ridgetown College, 1999).

Figure 1. Ontario hog marketings and producer numbers over time.



Source: Ontario Pork

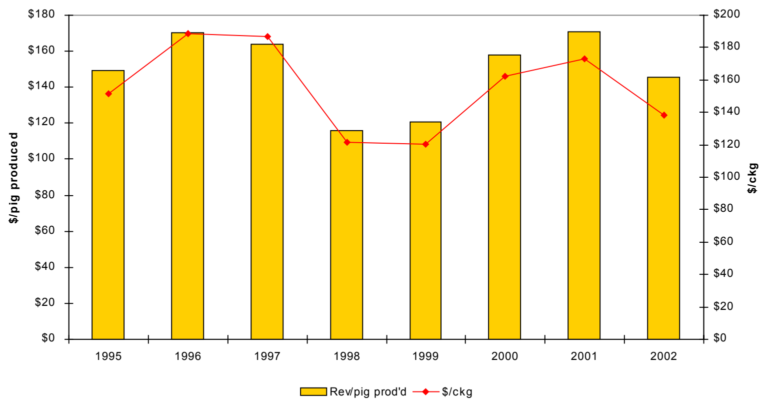
THE SWINE ENTERPRISE

The following discussion will focus on the swine enterprise and will not take into account other activities on the farm (i.e. cash cropping). Family labour has not been included in the calculation of expenses. The ODAP program provides analysis on a per pig produced basis. This is a calculated number that converts all pigs produced and sold to market hog equivalents taking into account all production and inventory changes. It is important to note that some of these farms had SEW or weaner pig sales in addition to market hog sales. Weaner pigs are converted to market hog equivalents using a factor of forty percent and SEW pigs are given a factor of twenty-five percent. The average number of pigs produced per farm by this group in 2002 was 4,260. The average number of sows on these farms was 275.

The average number of litters per sow per year was 2.27 with 10.7 piglets born alive and 9 piglets weaned per sow. The average weaning age was 22 days at a weight of 6.7 kg. The average market hog was shipped after 168 days at a live weight of 112.8 kg.

Figure 2 shows the average revenue per pig produced over time (note: revenue accounts for premiums/discounts, cull pig sales, and changes in accounts receivable and inventory). Also plotted on the graph is the average yearly market price ($/ckg). It is easy to see how revenue/pig has fluctuated with events such as the price crash in late 1998 or when prices have been higher (eg. in 1996, 1997, and 2001). In 1996 and 2001 revenue per pig was slightly over $170 whereas in 1998 it fell to $116 and in 1999 it was $120.97. The average for the 8 year period was $149.32.

Figure 2. Average revenue per pig produced.



Expenses per pig produced have been fairly consistent, averaging $134.68 over the 8 years. A closer look shows that feed makes up approximately 60% of total expenses each year. Feed expenses/pig produced are shown in Figure 3 for the years 1999 to 2002. Notice the $18/pig difference between 1999 and 2000. Depreciation expense is also fairly significant as shown in Figure 4. Note that this expense has grown steadily from $14.37 to $16.88/pig over the 4 years depicted. This will be due to the increase in buildings and equipment that has occurred with expansion and/or renovation of these farms over time.

Figure 3. Feed expenses/pig.

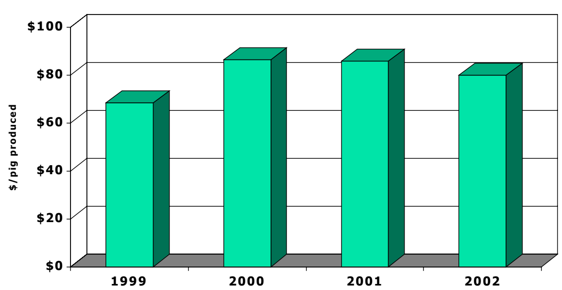
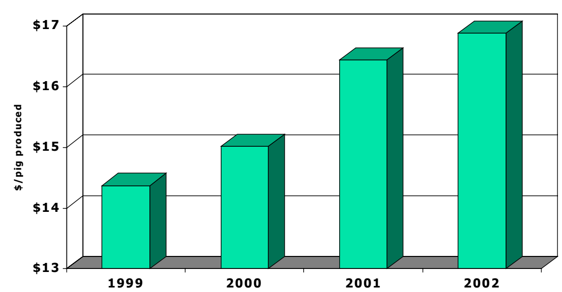


Figure 4. Depreciation expense/pig.



The resulting profit per pig per year is shown in Figure 5 and the average over this time period is $14.64 per pig. Note the -$17.71/pig loss in 1998 attributed to the low market prices. This graph shows a trend of 3 years of increasing profits followed by a year of small to negative profits.

THE BALANCE SHEET

Table 1 shows the balance sheet for the group of participants between 1997 and 2002. The balance sheet does take into account all aspects of the farm operation. It is important to note the increasing asset value over time. Total assets increased by 70%. The average of this group of farms, nearly $2.7 million in 2002, indicates that these farms have invested significantly in their farm businesses. Some of the increase in value is due to increases in livestock and buildings but it is mostly due to land. Some of the increase in land will be simply due to appreciation in land values but several participants have increased their land base during this time by purchasing additional farms. In 2002, the average total assets per sow per farm were $9,659 and the average amount of debt per sow was $3,635. Overall, total debt increased by approximately 34% (i.e. to nearly $1 million) between 1997 and 2002.

Figure 5. Average profit per pig produced.

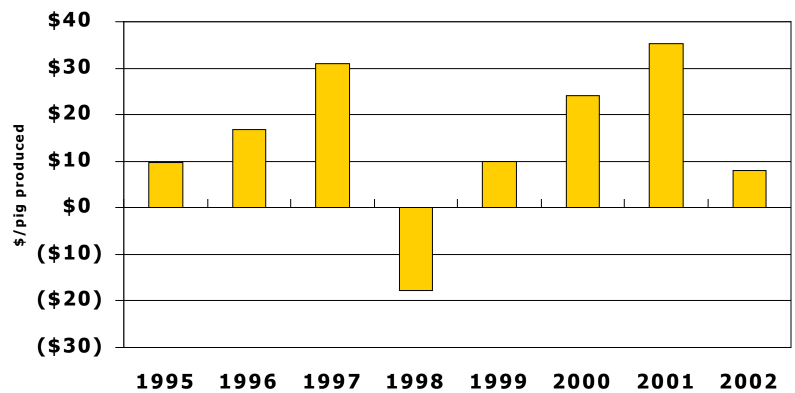


Table 1. Average ending balance sheet.

	1997	1998	1999	2000	2001	2002
Assets						
Mkt Lvstck	$148,338	$98,957	$107,806	$129,868	$150,427	$173,541
Brdg Lvstck	81,062	59,467	60,150	75,550	78,144	89,037
Buildings	382,915	382,819	459,979	514,684	548,102	634,042
Land	478,341	452,978	599,526	695,642	884,906	1,004,094
Total Assets	$1,559,693	$1,387,531	$1,720,675	$1,999,019	$2,327,168	$2,653,109
Liabilities						
Op. Loan	93,913	114,962	93,781	88253	123794	129792
Mortgage	338,423	359,719	349,392	417651	504845	679664
Total Liab.	$746,997	$718,223	$645,263	$661,139	$807,356	$998,337
Equity	$812,697	$669,308	$1,075,411	$1,337,880	$1,519,812	$1,654,772

The return on equity (ROE) averaged 9% during the 1995 to 2002 time period and there were some significant fluctuations (Figure 6). Certainly the low prices in 1998 played a significant role in the ROE for that year (-2.4%) however there was a strong rebound in 1999 and 2000. It is concerning to note the decreasing ROE since 2000.

FINANCIAL HEALTH

A scoring system was developed to analyze the financial health of the participating farms over time. Each farm received a score based on the criteria shown in Table 2. The lowest possible score was 3 and the highest was 12.

Figure 6. Average return on equity.

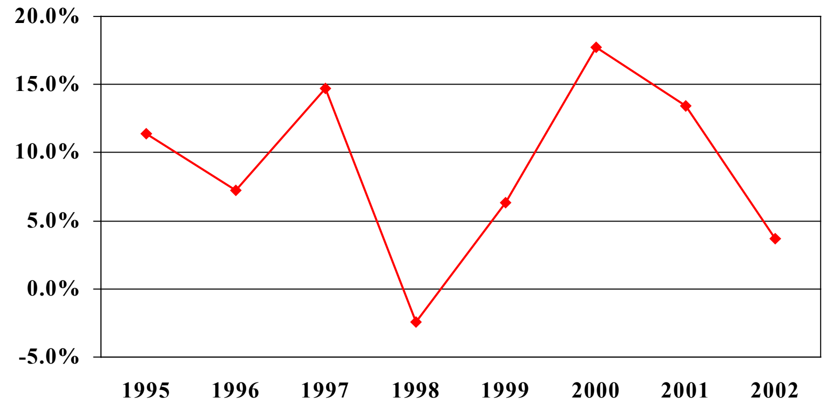
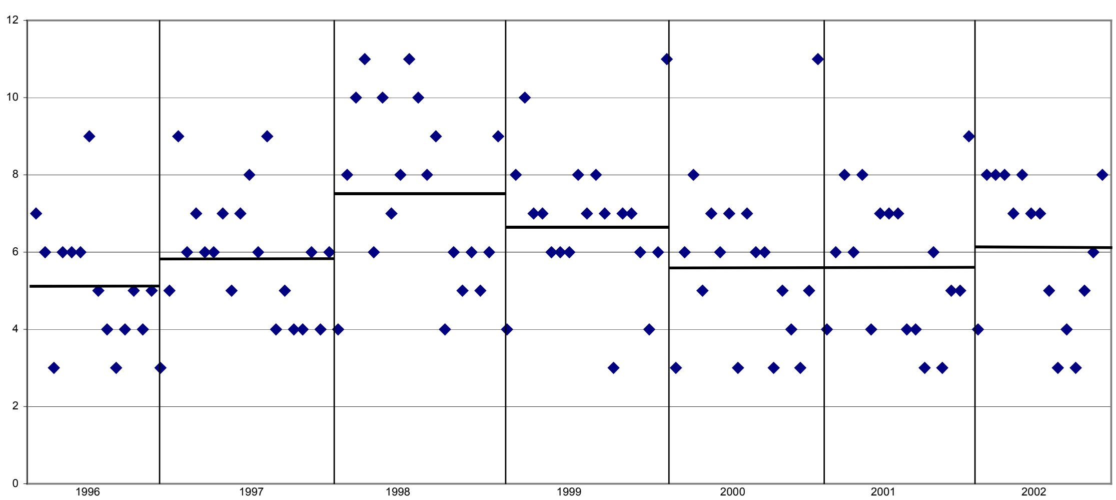


Table 2. Financial health scoring.

Score		Debt Servicing Ratio	% Equity (Ending)	Current Ratio
High Risk	4	> .30	< 25%	< 1.0
	3	.02 - .30	25 – 50%	1.0 – 1.5
	2	.10 - .20	50 – 75%	1.5 – 2.0
Low Risk	1	< .10	>75%	> 2.0

Figure 7 shows the ratings over time. The average of the dots for each year is included as a solid line. It makes sense that when the market price was low (i.e. as in 1998) the average financial health rating was higher at approximately 7.5. When market prices were higher (i.e. as in 2000) the rating was lower.

Figure 7. Financial health rating.



COMPARING PROFIT LEVELS

Size Versus Profit

It is a common belief that larger farms are more profitable. The ODAP data, however, shows that this is not necessarily true. Figure 8 below shows the average size and profit/pig/farm between 1999 and 2002 for 13 farms. There is no correlation between the size of farm (in terms of number of sows) and profit per pig produced. Some large farms report lower profit per pig than small farms.

Figure 8. Size vs. profit/pig.

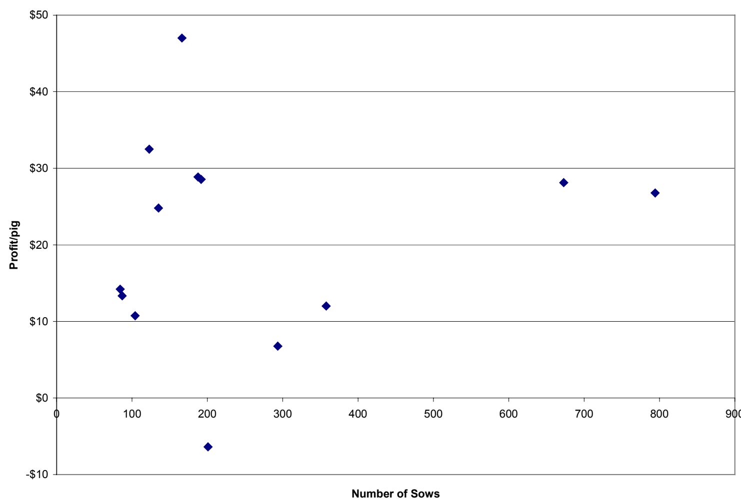


Table 3 shows the distribution of consistency of profit. Each of the 13 farms was analyzed over the 4 years to determine how often their profit/pig was higher than the group average for each year. It is interesting to note that 15% of the farms reported higher profit/pig in all 4 years. This means that these farms were above the group average in each of the 4 years. 31% reported high profit in only 1 year out of 4.

Table 3. Consistency of profit.

High profit/pig in:	% of Respondents
4 years out of 4	15%
3 years out of 4	16%
2 years out of 4	38%
1 year out of 4	31%

Productivity Versus Profit

From the original 13 farms above, a group of 8 farms was assembled for further analysis based on profit/pig produced. The 4 lowest and 4 highest farms were used to assess productivity as determined by kilograms of pork produced per sow. The group of lowest profit/pig farms averaged 1,536 kg pork/sow over the 4 years. The group of high profit/pig farms averaged 1,639 kg pork/sow. The resulting 103 kg difference represents approximately $42,700 more for the high profit farms (i.e. 103 kg x $1.51/kg = $155.53/sow x 275 sows).

Cost Control Versus Profit

Expenses were also analyzed in a similar way. Again, the 4 lowest and highest profit/pig produced farms were used. The expenses for the low profit/pig group averaged $145.41/pig produced while the high profit/pig group averaged $115.03. This indicates that keeping costs under control really does make a difference. Using these 2 groups of farms shows it can make a difference of $30.38/pig produced.

CONCLUSIONS

In summary, this group of farrow-to-finish farms has been profitable between 1995 and 2002 with the exception of 1998. Profitability has been decreasing since 2001 and is likely to continue into 2003 due to the low prices that were in effect for much of 2003. The average cost of production for the 8 years examined was $134.68 per hog produced. Increased size does not always mean increased profit/pig. There are many variables to take into account including health, genetics, feed, management, etc. It is important to focus on things such as cost control and productivity as well as getting the highest revenue possible.

Thanks and appreciation are extended to Agriculture and Agri-Food Canada for their generous financial support of this research and to the farm participants for sharing their time and information.

PRODUCTION CONTROL SYSTEMS FOR PIGS

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ABSTRACT

Management control requires a production system to have, amongst other things, the following components: 1. Real time and continuous measurement of body size and weight change. 2. Response prediction models that can be optimised to particular production circumstance. 3. Feed systems that can deliver, upon instruction, stated quantities and qualities of feed to the pigs. Central to the control system is the ability to assess pig growth frequently (daily) and without physical interference. Visual Imaging provides such opportunity. The paper reports that Visual Image Analysis is sufficiently accurate to provide the required tool, and models can be fitted effectively to individual production circumstance by modulation of few parameters. It also appears probable that Visual Imaging may be able to sort pigs according to their type.

INTRODUCTION

Growing pigs for meat is little different from other production processes:

- The rate of production (daily live weight gain) relates to the rate of input of the primary raw material (daily feed supply);
- The efficiency of production of the output is a function of the total quantity of input resource used (kg feed used per kg pig sold);
- Inefficiencies result in waste products (such as ammonia) that have disposal costs;
- The process is limited by the availability of the first limiting resource, which will likely be one of,
    - The quality of feed and of management inputs,
    - The ability of the pig to make use of the inputs presented to it;
- Management depends upon process control,
    - Production targets,
    - Measurement of the status of the product at any given moment,
    - The possibility of predictable correction of deviations from required performance.

Amongst management's tools would be:

- The genetic selection of the pig to grow high quality meat at the required rate and of the required ratio of lean to fat;
- The daily amount of feed supplied;
- The balance of energy to amino acid in the diet;

- The choice of the moment of slaughter (target size).

Effective use of these tools, and the decisions pertaining to their use, is necessarily an on-going (day-by-day) process, not least because:

- The amount of feed the pig requires changes daily as it grows;
- The balance of energy to amino acids required in the diet changes daily as the pig grows;
- Both of the above are affected by the ambient and the disease environment that fluctuates on a short time scale;
- The inherent potential of an individual batch of pigs is not well characterised at the point of entry into the grow-out unit;
- All the interacting elements of the production process are subject to short-term biological variation.

Presently, pig production is usually managed retrospectively, and not in real time. At worst, pigs are fed according to some general rules (nutrient requirements) pertaining to general populations and measured with pigs from various points in historical time. At best, pigs are fed according to the lessons learned from previous batches reared in like circumstances. Pig production systems therefore rarely use the available management tools to control the process and maximise the efficiency of production of meat of the required quality. There are three important reasons for this (Whittemore et al., 2001):

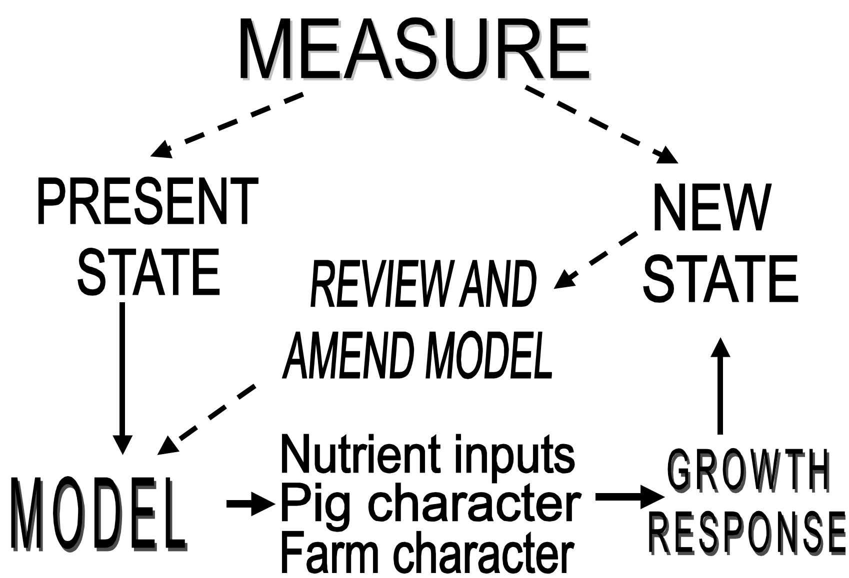
- The relationships between change in input (amount and quality of feed) and change in output (amount and quality of pig carcass) are inadequately known at the level of the individual production plant (farm). Such descriptors require to be flexed to fit the conditions prevailing to any given time, place and circumstances of production. There is a need for accurate and flexible models of pig nutrition and growth.
- The progress of the process is usually only poorly known. Short-term (and long-term) changes in growth rate are difficult to measure. The conventional (platform) weigh scale is not an effective tool for monitoring growth in the short term, and is not much used by managers for this purpose. There is a need for an effective way to monitor and measure the growth of pigs in real time.
- The most effective means of controlling the rate of pig growth and the fatness of the end product is by altering the amount and the composition of the feed supplied. As the deviations are in the short term, so also must be the corrective actions. Feeding systems that allow daily control of both amount and composition of diets fed are presently available. But they are rarely used to their full level because of inadequate monitoring of present positions of the pigs, and insufficient accuracy of prediction of consequences of changes to the pigs' diets. In the event, systems that can deliver variable quantities and qualities of feed on a daily basis are usually programmed to a preset pattern over the whole of the grow-out cycle. Computer-controlled feeding systems await management tools for their effective deployment.

In 1999 an applied research programme "**Integrated Management Systems for Pig Nutrition Control and Pollution Reduction**" was initiated to address these shortcomings in the effective control of the pig production process. It has just (2004) been completed, and the project is now going into active development with a view to commercial exploitation. This work has built upon previous basic research into video image analysis at the Silsoe Research Institute (Schofield, 1990; Marchant et. al., 1999; Schofield et. al., 1999). The IMS PIGS programme has involved research teams from Silsoe Research Institute (P. Scofield, D. Parsons, R. White), Edinburgh University (D. Green, A. Doeschl (PIC), C. Whittemore), Bristol University (A. Fisher, J. Wood) and ADAS (S. Carroll, R. Kay). The programme has been part of UK DEFRA LINK, and the industrial sponsors were Department for Environment, Food and Rural Affairs (DEFRA), Meat and Livestock Commission (MLC), BOCM Pauls Ltd., PIC (UK) Ltd., and Osborne (Europe) Ltd.

THE IMS PIG MODEL

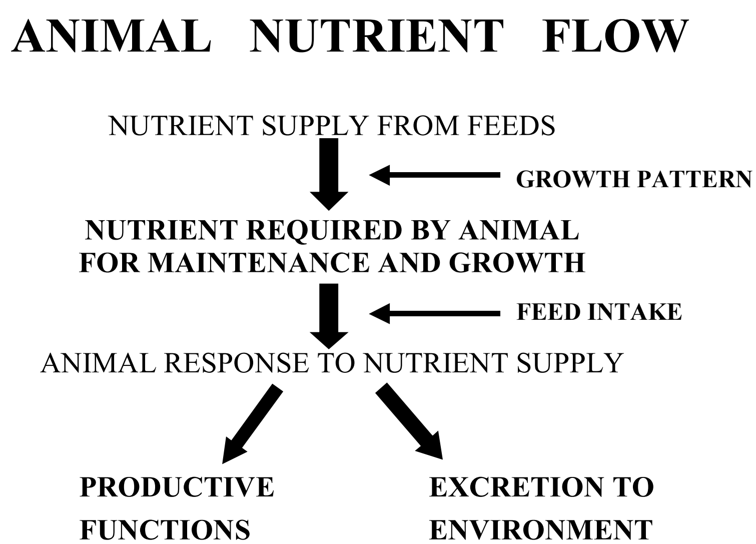
The details of the model have been reported by Green and Whittemore (2003). Its position in the management system is depicted in Figure 1.

Figure 1. Positioning of response prediction model within a management control system.



Importantly, the model is flexible enough to learn from its errors. Crucial to its use is an ability effectively to measure change in pig state. The model requires information on nutrient inputs, pig character and farm character. The structure is that shown in Figure 2. The IMS Pig Model links primary nutrients to tissue retention, determines variable efficiencies for energy and protein utilisation, and integrates nutrient cycling into a single system for maintenance and growth. These characteristics allow the model to be optimised on the basis of few parameter values. Recent findings have shown the model (like others before it) to be good at predicting the magnitude and direction of the growth response to nutrients, but poor at quantifying that response. Thus in a recent trial (Green et. al., 2004), the un-optimized model predicted end weight from the quantity and quality of feed input only to within 6 kg. [In effect, our ‘guess’ at the farm circumstances and the growth potential of the pigs was incorrect.] However, using the first half of the growth period to optimise the parameters M_D and B, the model predicted end weight to within 1 kg of end weight. The parameter B is the lean tissue growth rate parameter, essentially describing the pig genotype. The parameter M_D relates to the maintenance requirement for both energy and protein, and essentially describes the effects of disease upon the efficiency of nutrient use. Using the whole of the growth period to optimise M_D and B, pig weight was predicted to within 0.5 kg of end weight. This showed that manipulating only two parameters could optimise the model, and when flexed, the model was sufficiently accurate to be used in a management control context for particular (rather than general) production circumstances. The parameter B is the lean tissue growth rate parameter, essentially describing the pig genotype. The parameter M_D relates to the maintenance requirement for both energy and protein, and essentially describes the effects of disease upon the efficiency of nutrient use.

Figure 2. A general description of the IMS Pig response prediction model.



VISUAL IMAGE ANALYSIS (VIA)

The visual imaging system uses simple video camera technology to capture the image of the back of the pig as the camera looks down upon the pig. From the image, linear measurements can be taken automatically. Further, and most importantly, mathematical algorithms developed at Silsoe Research Institute (Marchant et. al., 1999) allow the outline of the body to be traced and quantified. Thus the area described by the outline of the pig (A4) can be determined. Early results showed that the relationship between the A4 area and weigh-platform weight was rather good (Figures 3 and 4). The original equation for “Large White x Landrace” pigs was:

Large White x Landrace Live weight = 0.052A4 – 32.

Figure 3. **Relationship between time (day) and the weight of a pig determined manually, and by visual imaging (VIA).**

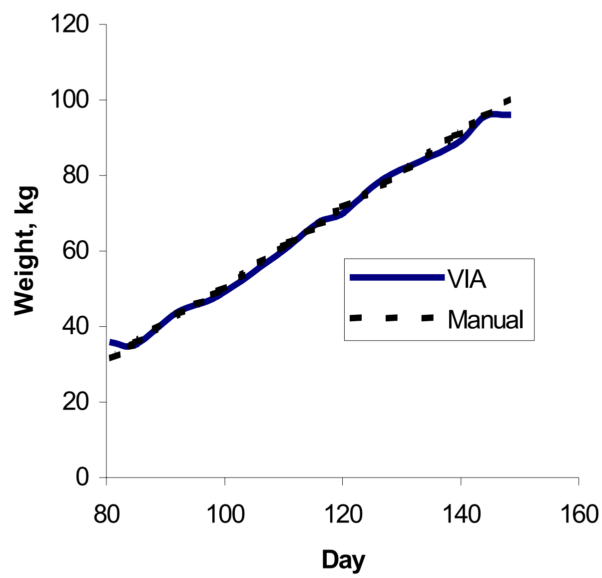
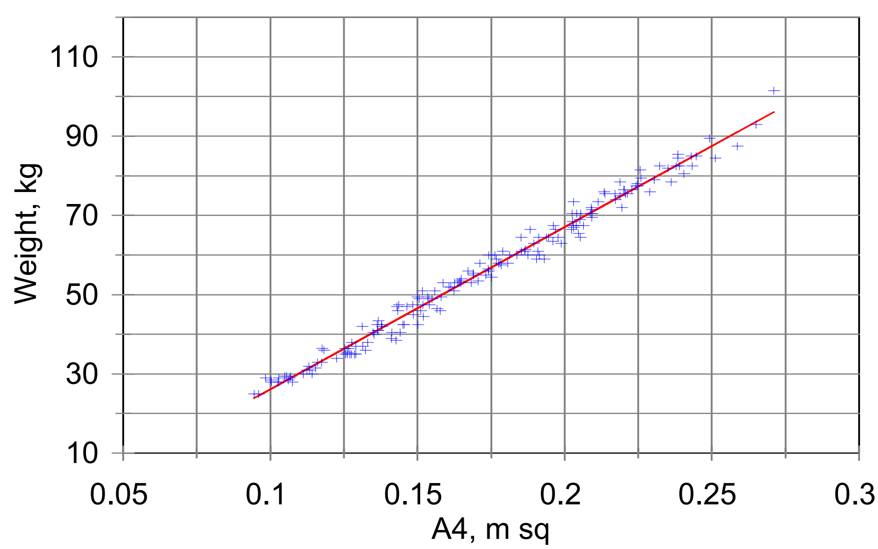


Figure 4. **Relationship between manual weight and A4 area.**



More recently (White et. al., 2003), the determination of this relationship was repeated in circumstances differing in time, place, research team and pig type. Three breed types were used; 25% Meishan, 50% Pietrain and 50% Landrace. The equations describing the relationship between A4 area as measured by visual imaging and live weight as measured by a weigh platform were:

"50% Landrace" Live weight = 0.049(0.0005)A4 – 29.8(0.74)

“50% Pietrain” Live weight = 0.052(0.0004)A4 – 38.5(0.67)
“25% Meishan” Live weight = 0.052(0.0004)A4 – 32.8(0.63).

We have interpreted these results as follows:

- The equations are robust;
- VIA A4 bears a close relationship to live weight, and by use of the equation can be used to determine live weight;
- As the equations differ between the pig types, it is important to be aware of pig type when setting up a system;
- As the equations differ between the pig types, it would appear the VIA system might be able to “identify” type differences. These could be important for carcass quality issues such as ham shape and joint proportions.

The most recent work, with Large White x Landrace pig types (again completed at a further different place and time, and with a different team), produced the following:

Landrace x Large White Live weight = 0.049(0.0006)A4 – 34.1(1.15),

which is similar to those determined for “Landrace” and Large White x Landrace pigs shown above. As all of these relationships were for pigs between 30 and 110 kg live weight, we further tested the relationship with heavier (Large White x Landrace) pigs, to find:

“80 – 150 kg pigs” Live weight = 0.041(0.002)A4 – 33.8(6.0).

It is yet to be ascertained whether the relative loss of precision and determination of slightly differing coefficients may be due to inherent (but stable) differences at higher live weights, or perhaps a tendency for curvilinearity in the line.

We believe that determining the status of pigs (size, shape, live weight) by VIA has advantages over a conventional platform weigher. Some of these are given in Table 1.

Table 1. Advantages of VIA in comparison to conventional weigh scales.

Visual Imaging	Weigh Platform
Estimates weight	Measures weight
Measures size	Does not
May discern pig shape	Does not
May discern pig type	Does not
Remote from pig	In contact with pig
Does not require operative	Does
Can take continuous measurements in real time	Can not
Electronic	Mechanical
Technology will improve	Will not

For effective control of the production system it is germane to ask how many days require to elapse between two estimates of weight before a safe determination of weight change can be made. Results are given in Table 2, from which it would appear that the VIA system requires only one more day than the weigh scale.

Table 2. Number of days elapsed until expected change in pig size becomes significant, for conventional platform weigher and VIA A4 data, assuming confidence limits of 80 % and 95 %.

		'25% Meishan' type	'50% Pietrain' type	'50% Landrace' type
Weigh-platform	80 % confidence	3	2	4
weight	95 % confidence	12	4	13
VIA A4 size	80 % confidence	3	4	5
	95 % confidence	8	9	10

The (albeit small) between-type differences in the relationship between weight and VIA A4 (above) left us with the possibility that the visual image could be used to sort animals on the basis of their shape. On the assumption that type ("25% Meishan, 50% Landrace, 50% Pietrain) was a reasonable description of shape (which would not always be the case due to natural variation within types), a neural network was used to test this hypothesis. Half the animals were presented to the network with a statement of their type together with the full data set for each pig from VIA. This was then used to sort the remaining half on the basis of the VIA data only. The results are presented in Table 3. The accuracy of prediction was high (73%, 83%, and 64%), particularly for the 50% Pietrain and 25% Meishan types. These types were also rarely confused.

Table 3. Confusion matrix for pig type.

Predicted type	Observed type		
	'25% Meishan'	'50% Pietrain'	'50% Landrace'
'25% Meishan'	72·5 %	4·2 %	17·1 %
'50% Pietrain'	7·7 %	83·0 %	18·7 %
'50% Landrace'	19·8 %	12·8 %	64·3 %

CONCLUSIONS

It is proposed that effective control of the pig production process is hampered by lack of the means to accurately determine, continuously and in real time, change in pig performances and deviations from targets. The evidence presented suggests the Visual Image Analysis may provide the resolution. Management assumes a realistic expectation of outcomes of corrective interference in particular farm circumstances. This can now be provided through the medium of a model that can be flexed through two (only) parameters. It would also appear that VIA could inform about pig shape, which may have benefits for carcass appraisal. The next steps will be to link the model and the VIA system to automatic computer-operated feeding systems which can control feed level and feed quality. When this step is complete, managers can not only be informed about and diagnose unwanted deviations in the production process, but like managers of other production processes, can also take timely remedial action.

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MAKING DECISIONS BASED ON ECONOMICS, NOT ONLY PERFORMANCE

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ABSTRACT

In this paper, we review the importance of having financial records to supplement production records. We need financial records for reporting and monitoring our financial well-being, for managing our costs and profitability and for making decisions that will impact the business. In the presentation, we will review examples of each application of financial records.

INTRODUCTION

A herd could be weaning 30 pigs/sow/year for an entire year and go broke. How? It could be a lack of inventory control, and therefore, too few sows bred, too few pigs weaned and fixed costs are spread over too few pigs. That is, the cost of production is too high. This is an example of a commonly accepted performance measure being overly simplistic and by itself, inadequate. We have adopted a second biologic measure to account for this inadequacy, and that is pigs weaned per week. We calculate the capacity of a sow facility and set a goal for throughput. This is a definite improvement. But I am guessing we all know farms where they are meeting throughput goals and yet are in financial trouble. In such a case, the problem may rest in the balance sheet, but might be made worse by income statement problems. That is, the cost of production could be too high and / or income too low, thereby increasing indebtedness on the balance sheet. So, while performance records are important to understand the biologic operation of the farm, financial records and their use in making decisions represent the “bottom line”.

FINANCIAL ACCOUNTING

Financial accounting concerns the preparation of reports for use by persons inside and outside the farm. Outside of agriculture, these financial statements conform to generally accepted accounting principles (GAAP). These principles have evolved over time and have been made acceptable by two independent bodies – Financial Accounting Standards Board (FASB) and the Securities and Exchange Commission (SEC), an agency of the US federal government. The equivalent advisory group for smaller agricultural producers is the Farm Financial Standards Board (FSSB). The FFSB provides a national forum to facilitate the development, review, communication and promotion of uniformity and integrity in both financial reporting and the analytical techniques useful for effective and realistic measurement of the financial position and performance.

Financial statements serve three important economic functions:

- They provide information to the owners and creditors of the farm about the current status and past financial performance.
- They provide a convenient way for owners and creditors to set performance targets and impose restrictions on the managers of the farm.
- They provide convenient templates for financial planning.

Chart of Accounts is used to classify data as it is accumulated in the general ledger for all financial reporting. The National Pork Board (NPB) recommends that producers keep at least the first level of accounts that include major income, expenses assets, liabilities and equity categories. The chart of accounts can be taken to three basic levels of production – breeding / gestation, nursery, finishing.

1. **Balance Sheet** – presents a snapshot at a point in time
    - Assets- items that have the ability or potential to provide future benefits to the firm. For example, cash, inventory and equipment.
      - Current = cash and convertible within 1 year
      - Non current = Property, plant & equipment (PPE)
        = cost - depreciation
    - Liabilities – creditors' claims on the assets of the firm
      - Current – due within 1 year
      - Non current
    - Equity or net worth – is the difference
      - Paid in capital – funds invested by shareholders for an ownership interest
      - Retained earnings – earnings realized by the firm; assets reinvested in the firm

- Assets = Liabilities + Shareholders' equity

- Market Value vs. Book (cost) Value. With GAAP, long term assets are valued at cost & depreciated over time (market valuations are allowed as supplemental information, but its accuracy is not commented on). Farm financial statements will give both cost and market value. Cost represents the purchase price minus accumulated depreciation. Market value is the value of the asset on the open market minus any selling commissions and potential taxes due to capital gains.

2. **Income Statement** - Has three parts
    - Revenue (pig sales and other pork revenues)
    - Expenses (feed, labor, utilities, vet, etc),
    - Profit (production profit, operating profit and net income)

    - Represents the results of operating activities for a period of time. The income statement links the balance sheet at the beginning to the balance sheet at the end of the period of time. Net income usually does not equal net cash flow.

- Accounts can be kept as accrual (recorded as production occurs or as expenses are committed) as or cash (recorded when received or paid, except for machinery, equipment of breeding stock which can be depreciated over time). Accrual more accurately reflects income generated during the period.

- Two forms of income are generally used. Gross revenues or value of farm production (VFP). Difference is how items purchased and held for subsequent sale are handled. In the gross revenue version, costs of these items are treated alike and listed with other operating costs. In the VFP version, costs of these items are subtracted from gross revenue to estimate the value added by farm after accounting for the purchase price of these items.

3. Cash Flow Statement
This statement shows cash flow into and out of the farm during a period of time. It is a useful supplement to the income statement because it focuses attention on the farm's cash position, and does not require judgment on what is a revenue item versus an expense (only cash flow). It shows how operations affected cash for the period. It has 3 sections.

- Operating activities
  - Cash inflows – cash outflows
- Investing activities
- Financing activities
  - Dividends, new loans

4. **Supporting Schedules and Notes** – for large enterprises

5. **Auditor's Opinion** – for large enterprises**.**

ANALYSIS USING FINANCIAL RATIOS

Analysts use financial ratios as one mode of analysis to better understand the farm's strengths and weaknesses, whether its fortunes are improving, and what its prospects are. These ratios are often compared with the ratios of a comparable set of companies and to ratios of recent past periods. The five types of ratios are profitability, turnover, financial leverage, liquidity, and market value ratios. Finally, it is helpful to organize the analysis of these ratios in a way that reveals the logical connections among them and their relation to the underlying operations of the firm.

Five measures of a farm's performance:

1. Profitability
   - use assets or equity as the denominator; use average of beginning and ending value for denominator.
     - Return on Assets (ROA) = Earnings Before Interest and Tax (EBIT) / Total Assets (avg.)
     - Return on Equity (ROE) = Net income / Equity (avg.)

2. Asset performance
    - farm's ability to use the assets
        - Asset turnover = Sales / Avg. Total Assets

3. Financial leverage (solvency)
    - a farm's capital structure and debt burden
        - Debt ratio = Total debt / Total assets
        - Interest Coverage = EBIT / Interest expense

4. Liquidity
    - a farm's ability to meet short term obligations and remain solvent
        - Current ratio = current assets / current liabilities
        - Quick or Acid test = (Cash + receivables) / Current liabilities
        - Working capital = Current assets (CA) – Current liabilities (CL)

5. Market value ratios
    - Used for publicly traded firms.
        - PE = Price per share / earnings per share
        - Market to Book = Price per share / Book value per share

Farm Standards to compare to (from Lee Fuchs at AgStar):

		Good	Moderate	Poor	
Profitability					
	ROE	>15%	8-15%	<8%	NI / Avg total equity
	ROA	>10%	6-10%	<6%	(NI + Int) / Avg total assets
	Operating profit margin	>9%	4-9%	<4%	(NI + Int) / Gross revenues
	Net profit margin	>6%	3-6%	<3%	NI / Gross Revenues
Solvency					
	Term debt / equity	<60%	60-100%	>100%	(Tot liab - curr liab) / Tot equity
	Adjusted debt / equity	<150%	150-200%	>200%	(tot liab - subord debt - deferred taxes) / Eq
Liquidity					
	Current ratio	>1.5	1.2-1.5	<1.2	current assets / current liab
	Working capital/gross revenues	>20%	5-20%	<5%	Work cap / gross rev
	Working capital / sow	>$400	$100-400	<$100	Work cap / # sows
	Interest Coverage	>4.0	2.0-4.0	<2.0	(NI + deprec + Int + taxes) / Interest
Farm performance					
	Asset turnover	>.9	.6-.9	<0.6	Gross rev / Total assets
	Depreciation / cwt	<$4.00	$4-5.00	>$5.00	Deprec / cwt sold
	Interest, lease & rent cost / cwt	<$5.00	$5-6.00	>$6.00	(Int + lease + rent exp) / cwt
	Labor cost / cwt	<$4.00	$4-6.00	>$6.00	Labor / cwt
	Feed Cost / cwt	<$22.00	$22-25.00	>$25.00	Feed exp / cwt
	Breakeven	<$38.00	$38-42	>$42.00	All accrued exp / cwt

RATIO ANALYSIS

Return on equity (ROE) is the ultimate measure of economic return of an investment. This is because ROE reflects the financial return on the amount the owners have invested. ROE can be compared to other potential investments of similar risk to determine if the return is adequate.

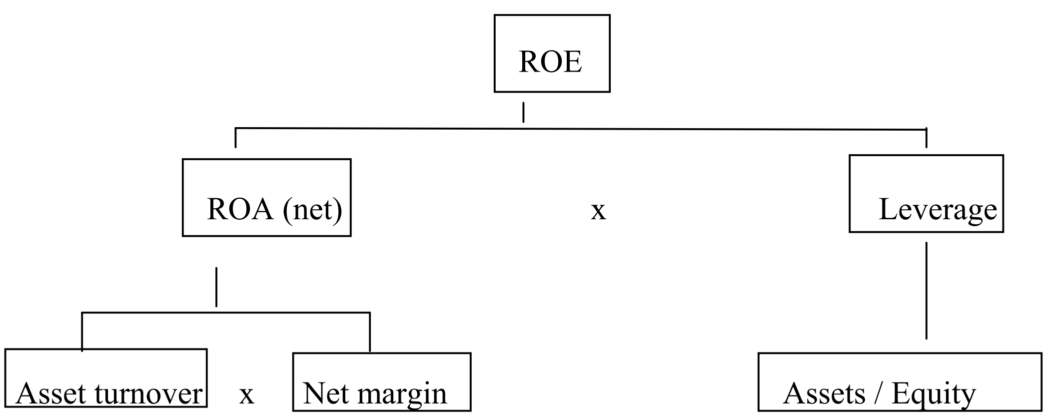
Return on Equity has three determinants
- Return on invested capital (composed of net fixed assets + working capital)
- Use of financial leverage (Interest Bearing Debt / Equity)
    - relative amount of debt
    - interest rate
- Tax policy

Note that effective use of leverage occurs when return on invested capital exceeds cost of debt (interest rate). There is a balance between increased risk when using debt financing & increased potential profitability.

Return On Assets (ROA) is a measure of how well the business is functioning independent of how it is financed. Use of debt (leverage) is a function of how one chooses to finance the business.

The ROE model was first developed and used in the early 1920s at the DuPont Corporation as a tool to help them manage their business. Accordingly, it is often referred to as the DuPont formula or the DuPont system of financial management. Since its early use at DuPont, it has become a commonly used tool in the non-agricultural business arena.

Figure 1. The Return on Equity Model.



Businesses are driven by the desire to maximize ROE, which in turn means maximizing ROA and optimizing leverage. ROA can be expressed as before tax (gross ROA) or after tax (Net ROA). Net ROA is a function of after-tax profit margin and asset turnover and is also referred to as the Return on Investment (ROI). The goal is to maximize ROA by effectively managing and balancing profit margin and asset turnover. Simplistically speaking, there are two extremes within the business world - firms with low margin per unit and high asset turnover (grocery stores) vs. firms with high margin per unit and low asset turnover (Boeing aircraft).

Consider a business with annual sales of $1,000,000, asset value of $500,000, and a net profit margin after tax of 7%. This would give the business a ROA for the year of 14%.

ROA (net) = asset turnover x net profit margin
= (total sales / asset value) x net profit margin
= ($1,000,000 / $500,000) x 7%
= 14%

The strength of the model is that it helps the owner/manager understand the importance of managing profit margin at the same time as asset turnover (throughput). The manager can also appreciate that it is possible to trade margin for turnover and maintain the same ROA (see Figure 2 and Table 1 below). Pork producers intuitively use the DuPont formula when making management decisions. Examples include changing wean age, feeding strategy and market weight.

Figure 2. Asset turnover and net profit margin of 14% ROA.

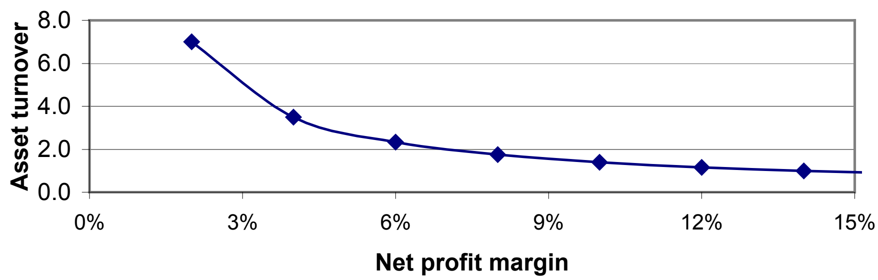


Table 1. Effect of net profit margin (%) and asset turnover on return on assets (%).

	Asset Turnover Ratio							
Margin	0.25	0.5	0.75	1	1.25	1.5	1.75	2
2%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
4%	1.0%	2.0%	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%
6%	1.5%	3.0%	4.5%	6.0%	7.5%	9.0%	10.5%	12.0%
8%	2.0%	4.0%	6.0%	8.0%	10.0%	12.0%	14.0%	16.0%
10%	2.5%	5.0%	7.5%	10.0%	12.5%	15.0%	17.5%	20.0%
12%	3.0%	6.0%	9.0%	12.0%	15.0%	18.0%	21.0%	24.0%
14%	3.5%	7.0%	10.5%	14.0%	17.5%	21.0%	24.5%	28.0%
16%	4.0%	8.0%	12.0%	16.0%	20.0%	24.0%	28.0%	32.0%
18%	4.5%	9.0%	13.5%	18.0%	22.5%	27.0%	31.5%	36.0%
20%	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%	35.0%	40.0%

To improve ROA, the manager needs to improve margin, turnover or both. Margin can be improved by:

- cutting costs, both variable and fixed,
- increasing per unit sales price (eg. quality or quantity premium, futures).

Turnover can be increased by:

- increasing sales volume,
- disposing of obsolete or unneeded inventory,
- identifying and dispose unused fixed assets, and
- speeding up collection of receivables; evaluate credit terms.

Examples

All over the world, banks' traditional business of taking deposits and lending out the proceeds is in terminal decline. US banks have 28% of the financial services market, half of what they had 20 years ago. While traditional sources of revenue are down, margin has also decreased from average 5.5% to 4% in the same time. In Germany also, banks' margin on lending has declined from 2-3% to just over 1%. Shareholders expect 15-20% return on the business' ROE, so what is a banker to do?

Looking at the ROE model, we see that cutting costs is one way of improving return. Cost cutting is one reason why the number of banks has decreased from 14,500 to 9,000 in the last 15 years in the US as mergers and consolidation eliminates inefficiencies. Consolidation in Europe and Japan will be more difficult because there are more state-owned banks. A second response is to increase revenues from alternative sources such as investment banking (fees and commission income) and/or lending to less credit-worthy customers. With the same efficiency of business management, an owner can increase ROE by taking on more debt. Therefore, a third response would be to take on more debt; that is, to borrow a higher percentage of total assets. As long as the gross return on asset is higher than the after-tax cost of debt, debt is being "effectively used". However, internationally active banks are not allowed to have less than 8% of total assets as equity; that is, they have a limit on the leverage they can have.

A second example is the personal computer industry. Profit margin is under extreme pressure and average price is expected to drop by a further 14% this year as the desktop computer has become a commodity. These low profits partly reflect over-capacity and competition for market share (sounds familiar!). Look at the ROE tree and consider the options. Computer firms are responding by becoming more cost-efficient (Dell), selling novel designs to capture higher price (Apple), seeking additional sources of revenues by offering other electronic goods (Gateway) or services (IBM), or considering whether they should be in a commodity business at all (Hewlett Packard). Companies that do not excel in efficient production or added-value services and sales are caught in between and are in major trouble (former Compaq).

Effective Use of Leverage

As stated above, ROE is a function of three major drivers; return on assets, use of debt (leverage) and taxes. A firm may also increase ROE by increasing ROA, but also by increasing the percentage of total assets financed by debt. This third component of the ROE tree is sometimes referred to as the equity multiplier (assets / equity). Increasing debt will increase the ROE as long as the gross ROA exceeds the cost of the debt. However, as debt increases, the risk position of the enterprise also increases.

Effective use of financial leverage is a management practice that many producers, and their lenders, have not mastered. In agriculture, the commodity risk that results from large variance in cash flow and profitability typically causes the belief that use of debt is not conducive to profitability. Agricultural lenders tend to be more conservative than non-agricultural lenders because of this large variance in producers' cash flows.

It is important to understand that use of debt, up to a point, is, in fact, conducive to profitability. But the proper measure of profitability should be in terms on ROE, which is where the DuPont Model again becomes very useful. Also, what makes debt conducive to profitability is that debt is a cheaper form of capital than equity. But again, up to a point. All capital is either debt capital or equity capital. And debt capital is cheaper (all else being equal) because the interest payments on debt are tax deductible. Also, payments on debt take priority over payments on equity so risk to the lender is typically less than the risk to the owner.

Therefore, use of debt is cheaper than equity as long as the risks to the lender are not so great that the lender requires a premium (higher rates to generate higher returns) to have the incentive to make the loan. This is the risk - reward trade-off. But if the debt levels are too high and/or profitability is highly volatile (and there is a correlation between low equity and volatile profitability), the lender begins to take on the same risks as the owner. In reality, if the lender perceives the risks as high, the loan is not made at any rate because the lender does not want to take the same risks as the owner even with premiums.

In agriculture, the commodity risks tend to dictate that financial leverage needs to be low to keep the risks to the lender satisfactory without causing the lender to require a premium. However, if the producer implements proper risk management measures, the risks to the lender are reduced and the lender can allow higher leverage. Proper risk management measures stabilize profitability. When this is done properly, the risks taken by the lender due to the higher leverage are more than offset by the risk management measures implemented by the producer. Therefore, the lender allows higher leverage without requiring a premium. The higher leverage then can result in a higher ROE.

The DuPont model provides a tool to understand the risk - reward trade-off, as well as a tool to measure the value in stabilizing profitability that can result in a more effective use of leverage.

- Higher leverage (more debt) causes more risk to be assumed by the lender. Risk management measures utilized by the borrower can reduce some of this risk.

- The more risk assumed by the lender the more reward (higher interest rates) is expected by the lender as incentive to make the investment (loan).

MANAGERIAL ACCOUNTING

Managerial (cost) accounting can help us determine:
- cost of production
- incremental or marginal costs
- analysis of breakeven points
- cost-volume-profit relationships
- asset utilization by cost or profit center

Production costs are usually classified as **fixed or variable**. Fixed costs do not change with the level of output and typically include depreciation, taxes, insurance, and interest. Variable costs change with output and include feed, propane, veterinary and health expenses. As the planning horizon lengthens, more costs become variable such that in the long run, all costs are variable.

Only variable costs should be considered in deciding how much to produce in the short run. A production function expresses the relationship between use of inputs and products produced. It will show the **marginal productivity** as inputs are increased. The optimum production level is where marginal cost equals the marginal value of product (where margin over variable costs (MOVC) = $0).

Profit Center vs. Cost Center

Profit centers are the profit making activities within the business; eg. pork.
- Measuring profit
  - Production profit = revenue from sale of pigs minus production costs but excluding general administration (G&A) and financing costs.
  - Operating profit = production profit – G&A
  - Net income = Operating profit – financing costs
- Breakevens
  - Production breakeven = production cost for the profit center, excluding G&A and financing.
  - Operating breakeven = production cost + G & A
  - Total breakeven = production cost + G&A + financing costs

Cost centers support activities important to and used by the profit center; i.e. transportation, feed mill, sow site. These should not be set up as separate accounts unless enough dollars are involved that warrant the time and effort to improve performance, and a person is assigned for managing and controlling costs and activities of the cost center.

Budgeting & Cost Control

- This was well described recently by Dr. Gary Dial at the 2003 Leman Swine Conference. To summarize, cost management occurs at 2 levels. First, one must control the purchase price of inputs. This includes facility costs, feed, manure management, gilt replacements and semen, supplies, labor and utilities. The second level is the use of these inputs at farm level. Dr. Dial describes a 6-step approach to controlling use:
  - Set performance budgets that accurately project throughput,
  - Establish unit-use budgets to predict line-item costs for all inputs for the income statement,
  - Identify cost variances (differences in budgeted vs. actual) as they occur,
  - Use compliance reports to identify input wastage,
  - Link production and line-item variances to identify financial opportunities,
  - Empower farm staff to drive out costs.

  To quote Dr. Dial, *"for cost management to be effective, a 'low-cost culture' must be created. This usually requires that biological endpoints, at least initially, be de-emphasized at the expense of financial endpoints.*" What is your break-even cost? Or, what is your cost / weaned pig? And just as important, where are your opportunities for decreasing this cost?

Evaluating Inventory

- Inventory can be valued as "cost" or "value". NPB recommends using cost of production as value (NPB spreadsheet available to help calculate the value). Costs associated with inventory should be carried on the balance sheet as pig inventory asset.
- Home raised corn inventory can be valued at market price. After transfer to production, it should be valued at cost.

Depreciation

- Breeding stock should be depreciated over the estimated life of the animal; 2-2.5 years for sows and 2 years for boars at straight line. Salvage value is cull value. First-in, first-out cost flow.
- Buildings are 15 year at declining balance (150%) until straight line is greater. Salvage value for shell and concrete if at all.
- Equipment over useful life with declining balance method. Salvage value is scrap value.

MAKING DECISIONS WITH PARTIAL BUDGETS

Some decisions are major with an impact for many years and involving major investment and often capital expenditures. For example, should we construct a gilt development barn? Or, should we sell the pigs at weaning on contract or construct facilities to market them ourselves? On the other hand, many decisions are relatively narrow in impact and short term in nature. For example, should we hire another person for farrowing? Or, should we vaccinate for influenza? A partial budget is an economic analytic method for simple decisions where the time period is relatively short term and the outcome does not have a high degree of uncertainty. Partial budgets are relatively simple because they are restricted to estimating the change or **incremental** effect of the decision.

Every partial budget uses the same basic equation:

increased revenues associated with the decision
+ decreased costs
- increased costs
<u>- decreased revenues</u>
= change in revenue

Sensitivity analysis is a tool that allows us to assess the impact of the model's assumptions on the outcome. In a sensitivity analysis, we change one parameter (such as price) over a possible range of values while holding the rest of the variables in the analysis constant. In so doing, we explore the robustness of a partial budget outcome--i.e. how sensitive are the results of partial budgets to the assumptions in the analysis?

TIME VALUE OF MONEY

For the major decisions where the impact is over a number of years, a more complex analytic method is required. This may involve understanding the time value of money. In simple terms, a dollar is worth more today than tomorrow and therefore the time value of money needs to be taken into account. This is increasingly true as inflation increases. Time value of money has 3 principles:

1. You can invest it today and earn interest and have more tomorrow.
2. Purchasing power of tomorrow's dollar is worth less due to inflation.
3. Money expected in the future is not a sure thing.

PV = present value of the amount today.
FV = future value of the amount at some point in the future.
i = interest rate, expressed as % / year; referred to as discount rate when calculating present value.
n = number of years that we are accounting for
pmt = payment made periodically (e.g. annual)

Suppose we can earn 10% on $1.00. One year from now, I should have:
$\$1 + \$1 \times .10$
$= \$1 \times (1+.10)$
$= \$1.10$

Two years from now, I will have initial investment plus interest plus interest on the interest. This is called compounding which is the process of going from *PV* to *FV*. The future value of $1 earning interest at rate i per period for n periods is $(1+i)^n$.

$\$1.00 + \$1.00 \times .10 + \$1.00 \times .10$
$= \$1.00 \times (1+.10)^2$

The interest earned on the original principal is called **simple interest**. Interest earned on interest already paid is called **compound interest**. Total interest earned is the sum of the simple and compound interest. Frequency of compounding has a cumulative effect on the earned interest.

The generic formula is: or
$FV = PV (1+i)^n$ **$PV = FV / (1+ i)^n$**

Rule of 72 – the number of years it takes to double an investment is equal to the number 72 divided by the interest rate in %/year.

Multiple cash flows - One can make financial decisions by comparing the present values of streams of expected future cash flows resulting from alternative courses of action. Multiple cash flows is when there are more than one cash inflow in the future. Use a **timeline** to analyze the value. Start with negative number to denote the initial investment. Present value of the stream of cash flows equals the sum of each year's PV. The resulting cumulative PV is also the NPV.

Year	1	2	3	4
Cash inflow	-1000	400	400	400

Annuity is a stream of cash flows with the same payment every year. Need to specify whether the payment is at beginning of each period such as with a savings plan (immediate annuity) or at the end of period such as a mortgage (ordinary annuity).

A **perpetuity** is a stream of cash flows that continue forever. The PV = (payment / i).

Amortization is the process of paying off a loan's principal over the term of the loan. The amortization schedule will list the principal and interest payments.

Inflation favors debtors. If an interest rate on a savings plan is 3% and inflation is 3%, the purchasing power of my dollar does not increase. To account for this, we refer to **real and nominal interest rates**, with nominal interest rate being adjusted for inflation to give the real interest rate. When discounting a stream of cash flows, use nominal rate for nominal dollars and real rate for real dollars.

Real interest rate = (Nominal interest rate – rate of inflation) / (1 + Rate of inflation)

CAPITAL BUDGETING

This is the technique of assessing the profitability of specific investments, usually capital expenditures. The unit of analysis in capital budgeting is the investment project. From a finance perspective, investment projects are best thought of as consisting of a series of contingent cash flows over time, whose amount and timing are partially under the control of management. Most investment projects requiring capital expenditures fall into three categories: new products, cost reduction, and replacement. Ideas for investment projects can come from customers and competitors, or from within the firm's own R&D or production departments.

The objective of capital budgeting procedures is to assure that only projects which increase **shareholder value** (or at least do not reduce it) are undertaken. This capital budgeting process involves coming up with ideas for investment projects, evaluating the proposals and deciding which to accept. The benefits incur over time and therefore, the analysis can be thought of as a partial budget over time.

Effective decision making entails:
- having accurate financial data
- determining the incremental effect of the decision over time
- determining whether the expected return exceeds alternative investments
- considering the risk of decision (sensitivity analysis)

Most financial analyses:
- do a partial budget for only 1 period of time (eg. 1 yr) and state a benefit : cost,
- examine benefit over time but don't adjust values to present value,
- do not consider tax advantages of borrowing, and/or
- have no sensitivity analysis.

Concepts in the Discounted Cash Flow (DCF) decision model:
Projects may be evaluated using a discounted cash flow procedure wherein the incremental cash flows associated with the project are estimated and their NPV is calculated using a risk-adjusted discount rate, which should reflect the risk of the project.

Incremental change in income
- After-Tax Operating Cash Flow (ATOCF)
- Discounted to Present Value
- Use of Other Peoples' Money (i.e. debt),
- Residual value (perpetuity, liquidation or salvage)
- Cumulative Present Value (NPV) & Internal Rate of Return (IRR), Payback and Discounted payback,
- Sensitivity analysis of key drivers

Incremental change in income
- it is essential to isolate the incremental effect of the investment decision (with vs. without the investment)
- an annual partial budget is extremely useful to do this:
  = (additional income + reduced expenses) - (reduced income + increased expenses)
- does not include sunk costs

After-tax operating cash flow (ATOCF)

Cash flow from operations = Sales
- Operating expenses including operating int. + taxes
+ Depreciation (non cash expense)
- Change in working capital
- Other capital expenditures required to conduct the project,

Why separate operating from finance?

- Need to capture the performance and profitability of the business (operations), independent of how it is financed (use IRR)
- The effect of financing decisions is captured in the cost of capital (use cumulative present value)

Why after tax?

- Cost of capital is calculated after tax (incorporating tax shield for interest).
- Implications to the investors are after tax.

Annual after-tax cash flow is composed of:

- Return on invested capital
- Recovery of invested capital
- "Excess return" is the return beyond the return and recovery of invested capital (referred to as "Economic Value Added" (EVA).

Residual value

- Perpetuity method assumes that after the forecast period, the investment will earn on average, the cost of capital, forever.

$$\text{Residual value} = \frac{\text{Perpetuity cash flow}}{\text{Cost of capital}}$$

- Alternatively, if a herd is planning to exit the business, residual value could be the liquidation value (book, market or salvage value).
- Most conservative is to assume no or even a negative residual value.

Discounting

- is finding the present value of some future amount. The present value of $1 discounted at rate i per period for n periods is $1/(1+i)^n$.
- Discount rate is the rate used to calculate the present value of future cash flows
- Rate of inflation is commonly used but this is inadequate for investment decisions.
    - We often use the opportunity cost of capital as the discount rate.
    - Risk-Adjusted Discount Rate (RADR) = discount rate adjusted for business and financial risk (weighted average cost of capital or WACC).
    - If the project happens to be a "mini-replica" of the assets currently held by the farm, then management should use the farm's cost of capital in computing the project's net present value. However, sometimes it may be necessary to use a discount rate, which is totally unrelated to the cost of capital of the firm's current operations. The correct cost of capital is the one applicable to farms in the same industry as the new project.

Measures of return

1. **Net Present Value (NPV)**

- NPV is the difference between the present value of all future cash inflows minus the present value of the investments. Often a project is accepted if the NPV is positive and rejected otherwise.

2. **Internal Rate of Return (IRR)**

- A second method for evaluating capital expenditure proposals. Discount rate at which the net present value (NPV) of the investment is zero i.e. discount rate that makes the PV of the future cash inflows equal to the initial outlay.

3. **Payback**

- Payback period is the time since investment is made that it takes for investment amount to be regained in nominal dollars
- Discounted cash flow payback period is the time it takes for the investment to be regained PLUS implicit interest computed at the project's cost of capital.

Sensitivity analysis of key drivers

- We rarely know exact anticipated costs and benefits.
- Key drivers are those components of incremental income that have most influence on the projected profit:
  - feed efficiency
  - premium / pig
  - market price
  - the projected investment amount

CONCLUSIONS

Having production records, without financial, is a recipe for failure. Our nature is to tend to improve whatever we are focused on. Therefore, it is imperative that we focus on the right measures. Managing costs, optimizing productivity, maintaining inventories, and effective marketing will lead to profitability. This requires us to have good financial records to complement our production records.

BREAK-OUT SESSIONS

CONTROLLING E. COLI IN THE WEANED PIG

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ABSTRACT

Cold Springs Farm's first significant encounter with post weaning E. coli K88 infection dates back to October 1997. Outbreaks have resulted in substantial mortality and reductions in growth rates. Since 1997, Cold Springs Farm has undergone many changes in order to resolve the E. coli problem. Although the frequency of outbreaks and the severity of E. coli have been reduced substantially, it continues to be an issue within some of the production systems within Cold Springs Farm.

The E. coli problem appears to be multifactorial. All areas of production including environment, management, cleanliness, disinfections, pig flow, medications and diet appear to be contributors.

INTRODUCTION

At Cold Springs Farm, piglets are weaned between 17 and 20 days of age and moved to isolated nurseries. Most nurseries have been built in the last 7 years and hold about 2000 pigs in four rooms with 20 pens of 25 pigs per room. In each nursery unit, pigs are sourced from two or three sow herds and are mixed when entering the facility. Piglets are fed pelleted feed from large commercial feed mills according to a four phase feeding program. At arrival, the poorest pigs are kept separately in the first 2 pens in each room; diets are changed more slowly for these pigs. Rooms, but not the entire nursery are run on an all in - all out basis.

At Cold Springs Farm post weaning E. coli infection was first encountered in October 1997. Signs of E. coli infection include watery diarrhea, dehydration, sunken eyes, lethargy and death. Diagnostic testing confirmed the presence of the E. coli strain K88. Typically, signs of E. coli were showing up between 10 to 14 days post weaning. During this initial period there were times Cold Springs experienced mortality of up to 6%, and a reduction in average daily gain of over 25 grams. Since that time a number of preventative and treatment strategies have been implemented.

PREVENTION

Room Preparation

In order to control any nursery health challenge, it is necessary to get the pigs off to a good start, and this begins before their arrival. The rooms must be properly washed and disinfected, ensuring that all manure and organic matter is removed. It is also important to make sure the loading chutes and non-pig areas are cleaned and disinfected, as well as boots and coveralls. It is useful to utilize a pre-detergent before the final disinfectant, which helps in the cleaning process. In addition, it is beneficial to allow for adequate drying time prior to disinfecting, as well as rotating between different kinds of disinfectants. Applying disinfectants with a fogger ensures that the harder to reach places are disinfected. At this time, it is useful to sanitize and flush the waterlines as well as check the water nipples and flow rates.

Reducing Environmental Stress

Reducing environmental stresses helps to diminish the stress on the pigs. It is important to have the rooms pre-warmed and dry upon arrival. During the setup, ensure that the inlets are set evenly and that the fans and heaters are in good working condition. It is important to observe the behavior of the pigs to ensure that they are comfortable. Check the room controller for current temperature and record high and low temperatures on a daily basis. Minimizing temperature fluctuations is as important as ensuring the right temperature. In addition, it is important to keep the rooms draft free and with a humidity level of less then 60%. Electronic devices such as hobos that record fluctuations in temperature and humidity several times throughout the day are excellent tools to ensure rooms are set appropriately.

Feeding

Ensuring healthy nutritional intake early on helps to minimize problems later. For the first few days, it is beneficial to have additional feed mats or bowls (especially in the pens with smaller pigs). Keeping feeders adjusted properly and having fresh feed available at all times is vital. To prevent later problems, it is important to identify pigs that are not off to a good start as quickly as possible and move them to a recovery pen and feed them a gruel feed to get them back onto feed.

It is important to know the requirements of your pigs. To aid in this process we have found it beneficial to track feed intakes on a daily basis. This helps you to determine the proper energy and protein levels of the feed and to know when it is best to switch to the next phase of the diet. Switching from one ration to the next sometimes is enough to trigger an E. coli problem; therefore tracking intakes especially during these times can be of benefit. Cold Springs utilizes the following additional methods to control E. coli:

- Increasing the level of zinc to 3000 ppm during periods of known outbreaks has been effective in controlling E. coli. Since zinc can be only fed up to 3 weeks, it is important to have a step down program in place, allowing the gut to transition to a lower level. If it is too difficult to add another stage of feed, we have found that blending between two rations for up to 5-6 days helps in the transition.

- Starting at the time of arrival acidifying the drinking water to a pH of 4.0-5.0 at the drinking source has been effective. Due to different pH levels of well water each one of our facilities requires a different stock solution, and it is important to be checking and adjusting on a regular basis to make sure the drinking water for the pigs is at the appropriate level of pH. Having an acidifier in the feed also helps.
- Increasing the copper sulfate level reportedly helps to tighten the lower gut in cases of enteritis.
- Cold Springs have tried both soluble plasma and dietary egg-yolk products in the past. In addition, we previously tried vaccinating our sow herds with an autogenous vaccine in order to build up immunity. We found that these strategies did not help in our particular situation but they have been known to work for others.

TREATMENT

Treating individual pigs with an injectable medication is most effective. Removing sick pigs from its pen mates and into a recovery pen helps to reduce the spread of scour. It also helps to have an electrolyte solution available to aid in the recovery from dehydration. In cases where there are a significant number of sick pigs within a pen, we have found that treating all the pigs in that pen reduces the number of new cases.

Cold Springs has not had any significant improvement through using feed medication, and thus, we are currently not using these medications to control E. coli. We find that water medications generally are more effective and can be timed better. For example, either Neomycin or Apralan has given us the greatest success. One must check sensitivities received from the lab to know which medication will work best. We have found that in a few cases we have had lab results come back with E. coli being resistant to virtually everything. If it is not caught in the initial stages, it is much harder to control and water treatments are less effective. On occasion, we will pulse medication just prior to and throughout the typical period of the outbreak if we have had an outbreak in a number of rooms.

Since concurrent infections such as PRRS and Swine Flu exacerbate the E. coli problem, it is important to have proper vaccinations and treatments for such diseases. Cold Springs is currently exploring alternative ways of treating/preventing E. coli including the use of oral vaccines in the nursery and adding a high source fiber to the feed. In addition, Cold Springs will continue to assess pathogens and other health issues through routine blood work and post mortems.

CONCLUSIONS

Based on Cold Springs' experience with E. coli, we have found that focusing on prevention, by following best management practices, has led to the reduction in the number of cases and the severity. Collaboration with your veterinarian and nutritionist, as well as other producers, is imperative.

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CONTROLLING E. COLI IN THE WEANED PIG

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ABSTRACT

Post weaning colibacillosis is a bacterial disease caused by certain types of Escherichia coli and primarily affects pigs in the period shortly after weaning. The diarrhea causes metabolic acidosis, electrolyte imbalance and dehydration which leads to increased death loss and reduced production efficiency.

Economic losses are attributed to mortality and treatment costs of individual animals. Mortality may reach as high as 7%. A balanced approach to control has involved the simultaneous implementation of multiple interventions. There is strong scientific evidence for the use of antimicrobials. There is however little scientific evidence to support other best management practices. Control strategies have relied on empirical observation in the field.

ETIOLOGY

Escherichia coli (E. coli) are a group of gram negative flagellated bacteria that normally reside and multiply in the intestinal tract of all animals. E. coli normally increase in numbers during passage from the stomach through the duodenum, jejunum and ileum of the small intestine with the greatest numbers in the ileum. Some strains are hemolytic. Most virulence factors including hemolysins, toxins and adhesins are plasmid mediated. These plasmids contain genetic coding for virulence factors and can be transferred from one E. coli to another. This transfer of genetics via plasmids allows for more rapid change in the virulence of strains of E. coli. Gene probes are used to determine the genetic makeup of E. coli with respect to virulence factors.

The Enterotoxigenic E. coli (ETEC) are strains of E. coli that have the genetic ability to produce one or more of three different types of enterotoxins. Enterotoxins are "exotoxins", which are secreted by the E. coli and work external to the E. coli by causing a combination of deleterious effects on the function of intestinal cells. STa enterotoxins are small, heat stable, non immunogenic toxins. STa is less active in pigs older than two weeks of age. STb enterotoxins are heat stable, poorly immunogenic toxins. STb toxin is relatively common and is found in 70% of ETEC isolates. LT enterotoxins are heat labile toxins. Serotyping of individual strains of E. coli is based on specific characteristics that relate to several categories of antigens that the E. coli possess. Serotyping is one of the best ways to characterize strains of E. coli with respect to their virulence traits. Only the disease causing strains are generally typeable. "O" antigens are the somatic or cell body antigens. "K" antigens are the capsular or micro capsular antigens. "H" antigens are the flagellar antigens. "F" antigens are the fimbrial or pilus adhesin antigens. Many E. coli require colonization of mucus membranes to cause disease and as such these extra cellular proteinaceous appendages can be specific markers which can indicate disease causing ability. Examples of “F” antigen types involved in colibacillosis of pigs include the following: F4 (also called K88), F5 (also called K99), F6 (also called 987P), and F41. Three subgroups of K88 (K88ab, K88ac and K88ad) exist . An example of a problematic serotype of E. coli is O141:K91, which is F4 (K88) positive. This is a bacteria that possesses somatic antigen 141, capsular antigen 91 and fimbrial type 4 adhesive factor.

EPIDEMIOLOGY

Post weaning colibacillosis is a disease that may occur sporadically within an individual nursery. Sites, barns and rooms that are managed with either all-in all-out pig flow or continuous flow may be affected. Historically, F4 (K88) E. coli have been a common cause of preweaning piglet diarrhea. Vaccination of sows prior to farrowing has provided very effective passive lactational immunity to suckling pigs. Removal of the piglet from the sow at the time of weaning, removes this rich source of protective antibodies in milk. The pig very quickly becomes dependent on its’ own active immunity for protection. An apparent increase in the number of cases of post weaning colibacillosis was noted in the fall/winter of 1997 in Ontario. A search of the files from the Animal Health Laboratory, University of Guelph, and from the Veterinary Laboratory Services Branch, OMAF, revealed the following information:

Table 1. E. coli prevalence in Ontario.

Year	1992	1993	1994	1995	1996	1997	1998
K88 Cases	28	52	47	41	47	114	221
# of Herds	27	48	41	40	46	103	187

The mean age of piglets affected in 1998 was 25.6 days as compared to the average of 13.6 days in 1995. This tends to substantiate the reports from producers that post weaning pigs are more often affected, than piglets prior to weaning. In some cases pigs are clinically normal at weaning and have been found dead on arrival at the nursery after periods of transit of approximately 24 hours.

The most commonly accepted theory explains the increased incidence of this disease is the spread of a specific O149:K91 F4(K88) E. coli that elaborates all three enterotoxins. This seems to be borne out clinically with most persistent problematic cases of E. coli involving this specific serotype.

PATHOGENESIS

In order for Enteropathogenic E. coli to cause disease they must enter the intestinal tract, proliferate and attach to the intestinal lining and secrete their enterotoxins. Enterotoxigenic E. coli cause disease by attaching to enterocytes lining the intestine by means of their fimbrial attachment adhesins. Once attached they begin to secrete one or more of the enterotoxins which then cause the crypt cells to secrete fluids and electrolytes into the lumen of the intestine. These enterotoxins may also impair the absorption of fluid and electrolytes from the intestinal lumen. Fluid loss may be so severe that 30 to 40% of the pigs body weight may be lost into the lumen of the intestine within hours. Dehydration, electrolyte imbalance and metabolic acidosis and death will follow.

CLINICAL SIGNS

Pigs may be found dead with no previous clinical signs. These pigs often have distended bellies and sunken eyes. In many cases where sudden death has been a problem the F18 or Gut Edema strains of E. coli have been suspected. The F18 or Verotoxic E. coli has not been found to be a significant contributing factor to the problem in Ontario with the exception of a few isolated cases. The F18 E. coli is however a more significant player in some other regions of Canada and the United States.

The diarrhea may be mild to profuse. The consistency of the scour may be pasty to watery. The colour of the scour may be white, brown, green or very clear. Pigs may appear emaciated or "bony". A sunken eyed appearance becomes more prominent as the scour progresses. The pigs become depressed. Vomiting may occur occasionally. The skin may take on a blue discolouration especially over the extremities such as the ears, nose, toes and belly. The skin may also take on the appearance of dry parchment as dehydration progresses. The anus or perineum may have a red irritated appearance due to the irritation caused by alkaline faeces. The severity of clinical signs depends on the pig's age, immune status and the virulence factors of the E. coli involved. Endotoxic shock may be seen in some cases as the E. coli invades the blood stream late in the course of the disease.

DIAGNOSIS

The diagnosis of post weaning colibacillosis is based on a review of herd history, clinical signs, gross post mortem findings and histological lesions. The E. coli is often isolated in large numbers and relatively pure cultures from affected animals. Once the E. coli is isolated virulence factors such as enterotoxins can be further identified by gene probe. Gross post mortems may reveal dehydration, a dilated stomach containing undigested feed, venous infarcts on the greater curvature of the stomach and dilation of the intestine with fluid. There may be congestion of the intestine and other visceral organs. The gut content may be blood tinged. If the intestinal content has a blood tinged appearance the term "Haemorrhagic Gastro Enteritis" is often used. The lungs almost always deflate normally. Histological or microscopic examination reveals large numbers of bacteria adhering to the lining of the intestine, as well as vascular congestion and some haemorrhage. White blood cells can be seen migrating into the lamina propria and lumen of the intestine especially in the jejunum and ileum and occasionally the colon. Occasionally microthrombi or plugged up blood vessels are seen in other body organs.

TREATMENT, CONTROL AND PREVENTION

Treatment, control and prevention of post weaning colibacillosis caused by enterotoxigenic E. coli should include a review of the following points. It should be noted that there is little hard evidence regarding the effectiveness of many of the following interventions. This list is presented as a review of the current thought process.

Feed

Protein. The crude protein level must be adjusted for the age and weight of the pig as well as the average daily feed intake. Diets containing excess crude protein may contribute to E. coli scour because the excess crude protein acts as a food source for the E. coli thus enhancing its' growth. An increase in the amount of synthetic amino acids can help to reduce the amounts of crude protein required. Easily digestible proteins, such as those of animal origin, can be broken down and absorbed by the pig, making them less available to the bacteria.

Minerals. Calcium levels that are excessive have been suggested to act as a buffer which can then lead to an increase in gastrointestinal pH. This is especially true when limestone is used as a source of calcium and phosphorous. The recommended levels for calcium according to the National Research Council (NRC) is between 0.6% and 0.8%. Zinc oxide at levels of 1500 to 3000 ppm has been effective as an aid in the control for E. coli. In some countries the use of elevated levels of zinc in pig feeds is prohibited for environmental reasons. It is advisable to target the higher zinc levels during the problem period.

Fibre. Increasing the level of fibre has been reported to decrease the incidence of colibacillosis. Sugar beets, oats, alfalfa and barley are commonly suggested sources of fibre. By increasing the rate of passage in the small intestine there is reduced opportunity for proliferation and adherence of E. coli. Fermentation of fibre to short chain fatty acids will help to increase acidity. Non starch polysaccharides (NSP's) are the structural carbohydrates in cell walls and include the pectins, cellulose, and arabinose. They are soluble and gel forming when exposed to heat, which decreases the digestibility of other nutrients. This again will lead to increased food for E. coli growth. The goal here is to find the "optimum" amount of the "appropriate" fibre such that E. coli is better controlled with minimum negative effect on average daily feed intake, average daily gain, and feed efficiency. The use of enzymes to break down the fibre has been suggested. Growth rates may be reduced if the ration is so excessively bulky that the pig is unable to increase feed intake adequately to compensate for a lower energy density. Increased fibre may negatively affect pellet quality or flowability of feed through feed bins and feeders.

Acidifiers. Acidifiers can be added to feed to help reduce the stomach and intestinal pH. Organic acidifiers such as citric acid, sorbic acid, fumaric acid, lactic acid and formic acid can be added to the feed. Acid salts such as calcium formate and sodium formate can be used. Inorganic acids such as phosphoric acid and hydrochloric acid and sulphuric acid can be added to the feed but have not been as effective and may decrease performance significantly.

Feed Manufacturing. Heat treatment of feed such as pelleting, expansion or extrusion has been suggested to increase the proliferation of E. coli by increasing the amount of available nutrients required by the E. coli for growth. It has been suggested that in an increasing order of importance pelleting, expansion and extrusion will increase the relative risk of enterobacterial proliferation.

Feeder Management. It is essential that the newly weaned pig begin consuming feed as soon possible after weaning. Pigs that consume feed poorly for the first few days after weaning may have a tendency to engorge on feed at some later time when their appetite increases. A pig that can engorge or eat large meals will have more feed in their stomach than their stomach can adequately acidify. When the quantity of acid is not adequate, the pH of the stomach and intestinal contents will rise and create an environment more suitable for the growth of E. coli. In addition, lack of acid reduces the conversion of the digestive enzyme pepsinogen to pepsin. This leads to poorer protein digestibility and more food for E. coli growth. Once pigs are being fed ad libitum, self feeders should be adjusted so that 50% of the feed trough is visible. This means that the pigs are having to work at the agitators to get feed to drop into the trough from the hopper. This will force pigs to eat small meals frequently and reduce the opportunity for pigs to engorge.

Prebiotics. (eg. Mannin oligosaccharides or Biomass) have been suggested as a potential control. The proposed mode of action of prebiotics is to bind with E. coli and prevent their attachment to intestinal cells. In addition it has been suggested that prebiotics will stimulate the immune system. Most of the information that is available is based on in vitro experimentation.

Water

Acidity. E. coli grows best in an environment that is basic or a high pH. Maintaining a reduced water pH has been suggested as a means of control of the number of E. coli in the gastrointestinal tract. Citric acid, formic acid or proprionic acid can be added to water to maintain an acidic pH. The pH of farm water should normally be between 6.5 and 7.5. pH should be checked and adjusted on a daily basis to within a range of 5.5 to 6.0 depending on the severity of the scour problem. Water can be acidified from the time the pigs have entered the barn and continued throughout the nursery phase or pulsed on a strategic schedule depending on when the scour is most common.

Sanitation. Water sources and delivery systems may become contaminated with disease-causing organisms such as E. coli. Total coliforms and fecal coliforms in both the well and the water lines should be assessed at least yearly or when problems arise. This can be done through a Public Health Unit or a private lab.

Water Management. Pigs should have access to clean fresh water at all times. A water flow rate at the drinker of 0.5 litres per minute at 10 to 20 pounds pressure is recommended for the nursery.

Environment

Temperature. Chilling can contribute significantly to the increased prevalence of scour by increasing stress levels in affected pigs. Chilling has been observed to reduce the peristaltic activity in the gut of the neonatal pig, increasing the accumulation of E. coli and toxins in the intestine. Consider pre-warming the barn prior to pigs' arrival.

Manure Management. The incidence of post-weaning scour in general is greater in pigs housed on solid floors with no bedding and in pens where the flooring does not stay clean. This relationship is presumably due to an increase in the pathogen load within the pen.

Sanitation

Although the disease can be seen in brand new facilities that have never previously housed pigs it is still important to ensure that facilities are properly sanitized between batches, so as to reduce the pathogen challenge level. A review of washing procedures for removal of organic matter is important. The use of detergents for removal of fats and the use of biofilm removal products will allow the subsequent use of disinfectants to be optimized. Disinfectant selection, application and calibration should be reviewed.

Concurrent Disease

It is possible that some other concurrent disease may worsen the incidence and severity of colibacillosis. The control of internal parasites, external parasites and the presence of viral enteritis such as rotavirus or transmissible gastroenteritis (TGE) should be considered.

Hospital Pen/Recovery Pen

A scouring pig is a source of infection for pen mates and if removed promptly can reduce the spread of scour in the pen by reducing the challenge level to pen mates. In E. coli outbreaks involving a large proportion of the pigs, the use of sorting will have obvious limitations. Thin and dehydrated pigs that are slowly recovering from scour should be collected as a group to enable provision of extra nursing care.

Medication

Injectable, water and feed medications should be selected based on the sensitivity pattern of the Enteropathogenic E. coli isolates or based on response to treatment. Mass medication of affected or at risk pigs may make the problem worse if the disease causing E. coli is resistant as the medication only serves to reduce the populations of non disease causing bacteria allowing the disease causing strains to proliferate due to lack of competition. Electrolytes may be added to the water when pigs are scouring.

Vaccination

Passive Immunity. Colostral protection declines rapidly after birth and lactogenic induced immunity is no longer protective once the piglet stops suckling. Autogenous vaccines given to sows prior to farrowing may only help to reduce the prevalence of these organisms in the sow and subsequently the nursing pig population. Antibodies for E. coli, derived from the egg-yolks of hyper-immunized hens, can be added to nursery feeds to prevent the adhesion of the E. coli to receptors in the intestine. The inclusion of these antibodies has produced inconsistent results in the field. This may in part be due to differences in pathogen load seen on certain farms.

Active Immunity. Injectable intramuscular or subcutaneous vaccines can be designed for use in suckling or weaned piglets based on the enteropathogenic E. coli involved, but are probably only marginally useful. The main problem is the short time period between initial immunization and subsequent challenge post weaning. In addition, intramuscular administration of vaccines is not ideal for stimulating local gut immunity.

Oral vaccines made with a genetically engineered enteropathogenic E. coli is in the experimental stage. The vaccine contains a strain of non-scour causing E. coli designed to compete in the pigs stomach with scour causing E. coli. No antibiotic can be administered to orally inoculated pigs as this will kill the non-scour causing strain of E. coli and allow the scour causing E. coli to increase in numbers and cause scour. The oral vaccine is administered twice while pigs are nursing. The use of low virulence E. coli has been suggested where nonvirulent strains were unavailable. Oral vaccines using field strains of F4(K88) positive but non toxin producing E. coli have been reported to be successful in the USA and Canada. These E. coli are propagated and fed to pigs via the water on entry to the nursery in order to stimulate intestinal immunity prior to the onset of disease.

Competitive Inhibition

Probiotics have been suggested for use in control of post weaning colibacillosis. Probiotics may bind the E. coli or their binding site on the intestinal wall. Probiotics may compete with E. coli for nutrients. Some probiotics are capable of promoting acid production. Probiotic products can be added to feed or water. Heat treatment of feed by pelleting, extrusion or expansion must be evaluated as this processing may kill off the probiotics. Feed or water medication may also reduce the efficacy of the probiotic.

Biosecurity

Ensure that the breeding stock supplier has no history of post weaning colibacillosis. Review all elements of biosecurity that could be involved in entrance of E. coli.

Genetics

It is clear that there are some genotypes of pigs that do not possess the F4(K88) receptor site on their intestinal epithelial cells and as such these lines of pigs are resistant to certain E. coli, where the F4 attachment is a required virulence factor for the E. coli.

CONCLUSIONS

Escherichia coli continues to present challenges for swine producers in Ontario and across North America. It may be that the simultaneous use of a combination of interventions will be required in order to effect control.

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ABSTRACT

Clinical expression of disease associated with post weaning E. coli depends on the interplay of several factors. These include the dose of pathogen, a genetically susceptible pig population, diet composition, weight and age of weaned pig, environmental management, presence of confounding pathogens, and general farm management practices. Reducing the dose of E. coli exposure using sanitation procedures between groups is one of the most important means of controlling expression of disease associated with this bacterial infection.

INTRODUCTION

Nursery pig enteric disease continues to be prevalent in the modern swine industry. Adapting health improvement technologies such as segregated early weaning and all-in/all-out production schemes have not eliminated nursery enteric disease concerns. This enteric disease is predominantly associated with post weaning Escherichia coli (E. coli) infections. Clinical disease associated with post weaning E. coli is the classical representation of a multi factor caused disease and is the biological sum of a number of production system inputs. These inputs include presence and dose of pathogen, a genetically susceptible pig population, diet composition, weight and age of weaned pig, environmental management, presence of confounding pathogens, and general farm management practices (Madec and Josse, 1983; Madec et. al, 2000; Vannier et. al., 1983). Thus, controlling the expression of E. coli associated enteric disease of nursery pigs depends on managing these many interrelated challenges.

A large, epidemiological study designed to determine the relative risk of several factors associated with nursery pig enteric disease indicated that feeding management (33.6 odds ratio) in the first week after weaning and hygiene status (7.8 odds ratio) were two of the most important risk factors associated with decreased amounts of enteric disease in the nursery (Madec et. al., 1998). Since the impact of feeding management practices have been reviewed elsewhere, this paper will focus on reviewing hygiene procedures that are associated with decreased amounts of enteric disease in nursery pigs.

SANITATION PRACTICES

We continue to observe transmission of organisms that can survive relatively easily in the environment, such as E. coli and Salmonella. We attribute this to several factors that include the training of personnel on the importance of proper cleaning procedures. Operating the power washer is usually one of the lowest status and lowest paid positions on farms. Therefore, unmotivated and untrained personnel are many times depended on for this critical health control task. In some farms we have encouraged management to set up monitoring programs to ensure facilities are free of organic matter, dry, and warm before placement. These allow for easy identification of training needs and have resulted in greater motivation of staff since management is paying more attention to their aspect of the operation. A recent report by Irwin (2003) illustrates the importance that integrating sanitation protocols and personnel training can have on improving nursery performance.

The primary objective of hygiene practices is lowering the dose of infectious pathogens that can be transmitted from the environment. It has been well documented that animal performance is increased in "clean vs. dirty" environments and cleanliness is probably responsible for a large percentage of the growth performance benefits from all-in/all-out production (Klasing et. al, 1988; Amass et. al, 2001). Also, because the young pig is more susceptible to infections from enteric organisms, sanitation is especially critical for nursery facilities. Fortunately, most swine pathogens only survive for a brief amount of time outside the host in the absence of organic materials or moisture. However, recent reports indicate that environmental contamination is an important contributor of Salmonella infection. From one study in North Carolina, 27% (7/26) of drag samples obtained from all/in-all/out fully slatted finishing floors just prior to placement of pigs were found to be positive for salmonella (Davies et. al., 1999).

A survey of nursery hygiene practices on 129 French farms indicated several practices associated with decreased residual contamination (Madec et. al., 1999). These practices included damping of the rooms immediately after the removal of the pigs. The researchers hypothesized that damping prevented dying of the fecal matter and increased the ease and thoroughness of cleaning. Use of a detergent also was suggested as associated with decreasing residual contamination. However, in another study evaluating the impact of detergent the researchers were unable to detect any impact and residual contamination after thorough washing (Kihlstrom et. al., 2001). This indicates that using a detergent may be useful to improve the ease of cleaning. However, the detergents may not have much impact on the final amount of residual contamination if cleaning procedures are thorough.

As supported by several other studies, the study by Madec et. al. (1999) indicated that thorough cleaning of organic matter resulted in less residual contamination (Amass et. al., 2000, 2001; Kihlstrom et. al, 2001). Additionally, greater distances between the surface of the slurry and the floor were associated with less residual contamination. The authors attributed this risk factor to splash back and recontamination during the cleaning process. Finally, factors associated with disinfectant usage were important. These included proper dilution and application of disinfectant. An evaluation of disinfectant ability to reduce infectivity of porcine circovirus type 2 (PCV2) indicates that commonly available disinfectants vary widely in their ability to neutralize the virus (Royer et. al., 2001).

While boot baths are widely implemented on swine farms there appears to be little scientific literature supporting their usage. A recent study by Dr. Amass from Purdue indicates that disinfecting boots was ineffective at reducing bacterial load of boots if the fecal matter had not been removed before disinfecting (Amass et. al., 2000). She indicated that removal of fecal matter alone without disinfecting was responsible for a large proportion of bacterial load on the boots. A follow up study indicated that regardless of whether boots were cleaned with water first and then placed in a VirkonS bath for 30 seconds, or cleaned in a VirkonS boot bath, both methods resulted in rapid disinfection of boots. As with the previous study cleaning of the boots with scrubbing was an essential step of the process. Just stepping into the boot bath was not effective. Methods to evaluate cleaning protocols for residual contamination have been recently evaluated (Kelly et. al, 2001). Implications of this research indicate that subjective visual assessment of cleaning procedures is currently the most effective and practical method of evaluating the thoroughness of hygiene practices.

Further research by Amass et. al. (2003) provides practical information on the ability of production staff to transfer infectious organisms across groups of pigs. Using an enterotoxigenic E. coli challenge model to evaluate biosecurity procedures, they found that changing outerwear and hand washing did not prevent transfer of E. coli between groups of pigs. However, a complete change of clothing and showering did prevent transmission. This is in contrast to previous work with TGE virus and PRRS virus indicating that hand washing and changing outerwear was sufficient to prevent transmission (Amass et. al., 2000; Otake et. al., 2002). This information also can be interpreted to indicate that pathogens such as E. coli are more difficult to clean from the environment compared to TGE or PRRS virus.

CONCLUSIONS

Controlling E. coli in the weaned pig is a multi factor process. Lowering the dose of exposure is one step in this multi factor process. All/in-all/out and multi-site production systems have facilitated the ability to clean facilities between groups of pigs and limit the doses of pathogens such as E. coli. Recent research has illustrated key principles to further our understanding in carrying out sanitation protocols to minimize the impact of E. coli associated enteric disease.

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AUTOMATIC SORTERS

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Over the past two or three years there has been an increased interest in using automatic sorters to weigh and sort market hogs. Companies selling sorters are plentiful and options are endless. Many producers are making use of this technology. The main goals of implementing sorters are to reduce the labour involved in getting pigs to market, narrow carcass weight ranges to meet packer requirements and manage larger group housing systems.

There are two main ways of designing an automatic sorter system. For lack of a better analogy, they can be referred to as positive and negative flow systems. Each can work equally well, under appropriate conditions. A negative flow system is not a derogatory reference; it is basically a system that requires the pigs to go through the sorter to get to, or leave, a feeding/watering area. A positive flow system simply means the pigs always have access to feed and water, while being physically routed through a sorter to be weighed and sorted. Both systems have a list of pros and cons. When choosing a system to implement, it comes down to producer preference, or existing facility constraints. Most negative flow systems have groups of about 400-700 pigs on one sorter. Many positive flow systems are accommodating up to 2000 or more pigs on one sorter. If multiple groups of pigs are spaced evenly and the sorter can be moved easily, one sorter can reasonably handle three groups of pigs. This is the biggest pro for a positive flow system. A properly managed sorter that can accommodate 6000 pigs is very easy to justify. One good manager could, theoretically, weigh and sort 18000 pigs per year and ship them in a fairly narrow carcass weight window.

If labour reduction were the first goal of automatic sorters, consistently hitting specific weights in a narrow grid would be the second. Many packers are paying premiums to be in a certain weight range, or issuing penalties for being out of a certain weight range. As producers recognize the carcass weight of their genetics that gives the highest index or premium, they set their sorters to optimize the number of pigs that hit that carcass weight, to increase profitability. Positive flow systems are at a slight disadvantage, depending on the number of pigs on one sorter. Under most positive flow conditions, 2000 pigs do not go through one sorter in one day. This means that estimated average daily gains need to be used to adjust sorted weights on a daily basis. If pigs need to be booked for market a week in advance and it takes five days to put all the pigs through the sorter (maintaining a low stress level), there are twelve days of estimated average daily gain to consider. This variable can cause an increase in expected weight range at marketing. The negative flow system with less pigs, will have a shorter weigh period and increased accuracy.

The ability to manage larger group sizes has many benefits. Large group housing is generally less expensive to build. Large groups give the ability to pre-sort pigs, without fighting and subsequent weight loss. Large groups also offer the ability to implement sorters, to reduce weighing, sorting and shipping labour. Almost any barn can be converted to large group housing. Large groups are generally referred to, in this application, as 250 or more pigs. Old and new barns, with smaller pens can be converted to either positive, or negative flow systems. If the barn is fairly new and it isn't feasible to remove and rearrange the penning and equipment, the producer could simply open up a portion of the penning to set up a positive flow system. If the barns are older, or equipment is already in need of repairs, the best option might be to gut the whole thing and set up large groups in a negative flow system. It comes down to cost, manageability and suitability to individual barn designs.

The bottom line on implementing sorters into an existing or new facility, is that you can make almost any sorter work well in almost any barn, with either sorting system, but success will vary from one producer to the next. Producers need to determine what will work best for them, in their barns, to attain their goals.

USING ELECTRONIC SORTERS TO HANDLE LARGE GROUPS OF GROWING PIGS

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INTRODUCTION

In the past, pigs were grouped in pens of 30 or fewer. Today it is common to have pens with as many as 500 to 1000 with electronic sorters. The advantages of electronic sorters include labour savings, higher carcass index to increase income, and increased efficiency with more pigs in the same barn space.

PRODUCTION

Barn costs in systems with large group housing are lower because of the need for less penning. More pigs can be housed in a given space because of the lack of penning and hallways. Pig health in large pens is about the same as small pens but, with large groups, morbidity is about half. Aggression is not a problem, even when adding pigs to large groups, since timid pigs can easily escape their aggressors. As a result, tail biting is uncommon in these systems. Sorting pigs for market is simplified, since pigs are used to moving around and interacting with people, so there is less stress on the pigs.

DAY TO DAY CHORES

Housing pigs in large groups requires routine checks, which means entering the pen and walking amongst the pigs daily. However, checking drinkers and feeders takes less time in large pens compared to barns with small pens. You will also have pigs following you as you walk through the pigs. Lame and sick pigs should be pulled out and treated but when they have recovered, they can easily be returned to the large pen.

BARN LAYOUT AND SORTING IN LARGE GROUPS

Sorting hogs for market in large groups requires two to three (or more) people or an electronic sorter. There are two types of layouts:

1) Swing gate barn, where feeders and drinkers are placed throughout the barn. This is like a conventional barn with 25-30 pigs per pen with gates in each wall so pigs can go from pen

to pen without going in the hallway. A sorter is put in the hallway or offset. Pigs are forced down the barn and through the scale, which takes time and labour.

2) Kitchen style, the more common layout, where pigs go through the scale to get to feed and water. The pigs then go back out through one-way gates to a common sleeping area. With this layout you can use the sorter to feed two or three different diets at the same time to improve pig performance. This layout allows you to monitor average daily gains, project hog marketings on a daily basis if needed, and monitor health problems. Light pigs at the end of a batch can be added to another batch if necessary. Training pigs in a kitchen style layout is very straightforward, if barns are laid out properly.

Equipment Required

Regardless of the system used, the essential components of a sorter system include an electronic scale, one-way gates and an air compressor. Just as with barns with small pens, pull-out pens are needed to house sick or poor-doing pigs in large group systems.

CONCLUSIONS

Electronic sorters are becoming a standard for marketing hogs in today's market. All sorters will sort hogs, but you need one that sorts accurately.

HANDLING LARGE GROUPS OF GROWING PIGS

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ABSTRACT

After 30 years of designing grow-finish facilities with pens designed to house no more than 25-30 pigs, there is renewed interest by pork producers in facilities with group sizes over 100 pigs per pen. Reasons for this interest include marginally lower construction costs, the ability to stock pens at a higher density, the ability to mix pigs with minimal aggressive encounters and the use of auto-sort technology to identify pigs for slaughter. The major limits to use of large pens are people related. It becomes harder to isolate individual pigs for medical treatments or to sort-off pigs destined for slaughter as group sizes increase.

INTRODUCTION

The North American swine industry is rapidly moving towards wean-finish pig flow. In this system, 4-5 kg pigs (often 17 days of age), are placed in fully slatted pens where they remain until slaughter at 115-120 kg. Research has suggested pig performance in this management system is similar to pigs placed in conventional weaned pig nurseries and moved to grower-finisher facilities at 25-30 kg (Brumm et al, 2002; Wolter et. al, 2002). The main reasons cited by producers for adoption of wean-finish pig flow is labor savings, both from one less pig movement and one less facility to clean per growth cycle.

Typical modifications to traditional fully-slatted grow-finish facilities that producers make to accommodate wean-finish include:

- Supplemental zone heating such as heat lamps or infrared brooders.
- Mats under the supplemental zone heating area for 3-5 weeks.
- Wean-finish feeders or modified grow-finish feeders. These generally have solid dividers between spaces to prevent pigs from sleeping in the feeder and becoming trapped as they grow.
- Modified gating. Gating rods can be no more than 50 mm apart for weaned pigs, and gating must come within 35-50 mm of the floor so weaned pigs don't get their heads caught.
- Cup drinkers must be no more than 100 mm off the floor so weaned pigs can drink readily.

LARGE PEN BASICS

In addition to wean-finish, many production systems are using large pen designs for both wean-finish and grow-finish facilities. Generally these large pens consist of 80-250 pigs per pen. With adequate feeder and drinker space, data suggests no difference in performance versus conventional pens with 20-30 pigs per pen (Schmolke and Gonyou, 1999; Wolter et. al, 2001).

Most recently Payne et. al. (2001) examined the impact of group size (5 to 100 pigs per pen) on weaned pig performance and concluded that there was slight negative correlation between group size, growth rate and feed intake. However, they noted no evidence of increased variation in within-pen weights as group size increases. Turner et al. (2003) concluded that a large group size may compromise the growth performance of young pigs, but the long term consequences for other economically important traits is likely to be slight.

Possible reasons why large groups don't have as large a depression in performance as once believed (Kornegay and Notter, 1984) include:

- Flight zone. In large pens pigs have room to flee an aggressive encounter. Kay et al. (1999) observed that when groups of six unfamiliar sows were mixed, 50% of flight distances were less than 4.7 m and 95% less than 13.6m. In the US, typical pen dimensions for groups of 25-27 pigs are 3.1 m x 5.8 m. In this instance, an aggressive encounter begun in the center of the pen means the pig desiring to flee the encounter has insufficient distance. In a large pen of 100 pigs that often has dimensions of 6.1 m x 11.3 m, there is distance to flee the encounter.

- Sleeping area. Pigs prefer to sleep with the back against a solid surface. In small pens, the feeder and drinker are often located in the pen partition, meaning these devices are located in a preferred sleeping area. This leads to aggressive encounters as the pig that desires to eat or drink must make the sleeping/slumbering pig move. In large pens, feeding and drinking devices are often located in the center of the pen, leaving the perimeter as an undisturbed lying area.

- Social hierarchy. In small pens, there is clear evidence for dominant/submissive behaviors. In large pens, there is beginning to be suggestive evidence that the pigs go from a dominance/submissive behavior to a tolerant behavior. In large pens, it is possible to introduce new pigs at infrequent intervals with no visible disruption of the social order. In small pens, this introduction of unfamiliar pigs would result in aggressive encounters, biting, hot pigs, etc.

- Free space. In small pens, space is required for eating, drinking, fecal deposition and sleeping. In large pens, while these same activities occur, the space required is less per pig than in small pens. Thus, the pig reacts to large pens as though there were an increase in space allocation (McGlone and Newby, 1994).

LARGE PEN RECOMMENDATIONS

Based on the results of McGlone and Newby (1994), stocking density in large pens can be increased. While data is limited, many producers who stock small pens (25-30 pigs/pen) at 0.69 m^2/pig increase the density to 0.65 m^2/pig in large pens (100+ pigs/pen) with little impact on pig performance.

Individual treatment of sick pigs and sorting of market weight pigs are often cited as disadvantages of large group pens. Many producers utilize gating which can be secured on the feeder to provide a corner to trap a pig for individual treatment or to restrict pig movement in general when sorting.

Large pens require a different observation routine from that typically employed in facilities with small pens. Often times, the pigs will be laying some distance from the passageway. Thus, pig observation requires the caregiver to walk every pen every day. Many caregivers comment that identifying sick pigs is easier because there is room for the healthy pigs to scatter as the caregiver approaches. The last or slowest pigs to scatter are often the ones that deserve extra attention.

In addition to identification of sick pigs, daily human contact makes load-out for slaughter an easier process. Pigs reared in large pens are used to movement and human contact. This routine contact, along with the lack of social hierarchy, results in pigs that fight less during loading and transport to slaughter.

The difficulties of sorting pigs for slaughter have resulted in many producers installing "auto-sorters". These devices are automatic scales with two-way exit gates. Upon exit from the scale, pigs are directed by the gates to one of two pens based on a predetermined weight. Producers utilizing auto-sort technology report reductions in packer discounts and improved ease of loading. While not evaluated yet, there have been suggestions that auto-sort technology could be utilized to feed pigs in large pens according to weight. Possibilities include pulse dosing of growth promoting antibiotics, differential dosing of products such as ractopamine, or variations in lysine content.

CONCLUSIONS

The adoption of large pen technologies has challenged many producers and scientists' preconceived ideas of pig behavior. Large pen facilities have allowed for new technology, such as auto-sorting, to be utilized. These technologies are enabling pork producers to better manage the growth process.

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RISK MANAGEMENT STRATEGIES – A PRODUCER'S PERSPECTIVE

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YOU KNOW YOU HAVE TO GET SERIOUS ABOUT RISK MANAGEMENT WHEN...

1. You use your hard-earned equity to carry you through the bad times.
2. You think an extra hour in the barn will return more than an extra hour in the office.
3. Your recent cashflow projection was a flat line using $150 because that is the past 10 year average.
4. Your total complete feed cost has averaged 50% or more of sales.
5. You didn't sell pigs for June 02/03 for $185 guaranteed.

10 STEPS TO A SUCCESSFUL RISK MANAGEMENT PROGRAM

1. Learn how to use options, futures, Ontario Pork, and/or packer forward contracts.
2. Learn the relationship between the Canadian Dollar and hog income.
3. Get on the Internet and build your own library for resources and history.
4. Know your costs - including principal and interest (P & I), personal, depreciation, and allowance for capital purchases.
5. Book feed - go as long as you can when cheap.
6. Set benchmarks or targets for selling, eg. Margin/pig, return on equity (ROE), and sell in increments.
7. Analyze your options for marketing.
8. Risk management costs money. Our costs are $2 - 3 per pig per year.
9. Realize that no one will sell at every high and buy at every low.
10. You'll never lose if you sell for a profit.

Canada and United States – Market Information

Table 1. Canada and United States – Number of pigs in inventory and slaughtered.

Combined United States & Canada ('000 of Head)					Pigs Slaughtered per Sow
Year	Inventory			Number Slaughtered	
	Breeding	Market	Total Pigs		
1990	7,948	56,265	64,213	99,302	12.49
1991	7,954	56,695	64,649	102,026	12.83
1992	8,376	59,225	67,600	110,118	13.15
1993	8,272	60,587	68,859	108,019	13.06
1994	8,286	60,152	68,438	110,944	13.39
1995	8,255	63,026	71,281	111,877	13.55
1996	7,991	61,861	69,852	107,351	13.43
1997	7,773	59,831	67,604	107,133	13.78
1998	8,244	64,898	73,142	117,728	14.28
1999	7,986	66,648	74,634	120,268	15.06
2000	7,580	64,668	72,247	117,428	15.49
2001	7,676	65,037	72,714	118,504	15.44
2002	7,721	66,449	74,170	122,242	15.83
2003	7,590	66,595	74,185	123,067	16.24
2004	7,593	67,055	74,648		

Notes:

1. The inventory of pigs reported in the USDA Hogs & Pigs Report for the previous December 1st was used for the United States inventory of breeding and market pigs (i.e. the numbers reported in the 2004 row are from the December 1, 2003 inventory).
2. The inventory of pigs reported for Canada by Statistics Canada for January 1st of each year was used for the inventory of pigs in Canada.
3. The slaughter column represents the total number of pigs slaughtered in both the United States and Canada.
4. The pigs per sow is simply the total number of pigs slaughtered divided by the breeding herd number.

Table 2. Percentage (%) inventory and slaughter change from previous year.

Combined United States & Canada (% Change)					Pigs Slaughtered per Sow
Year	Inventory			Number Slaughtered	
	Breeding	Market	Total Pigs		
1991	0%	1%	1%	3%	3%
1992	5%	4%	5%	8%	3%
1993	-1%	2%	2%	-2%	-1%
1994	0%	-1%	-1%	3%	3%
1995	0%	5%	4%	1%	1%
1996	-3%	-2%	-2%	-4%	-1%
1997	-3%	-3%	-3%	0%	3%
1998	6%	8%	8%	10%	4%
1999	-3%	3%	2%	2%	5%
2000	-5%	-3%	-3%	-2%	3%
2001	1%	1%	1%	1%	0%
2002	1%	2%	2%	3%	3%
2003	-2%	0%	0%	1%	3%
2004	0%	1%	1%		

Note:

1. The percentage (%) change for each item is the percentage it changed compared to the previous year. i.e. The total number pigs at the beginning of 2004 compared to the beginning of 2003 were up 1%.

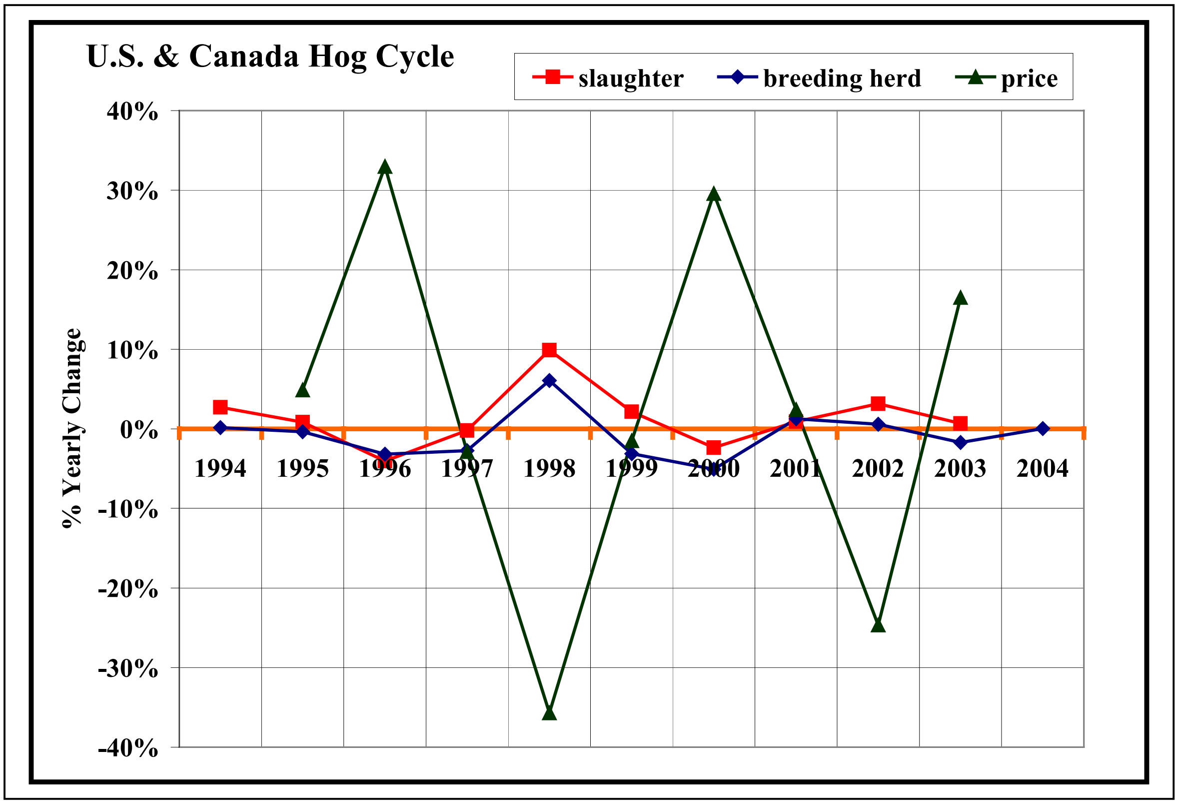
Table 3. Yearly average market hog prices with percentage (%) change from previous year.

Year	U.S. Price		Ontario Price	
	$/cwt., lean	% Change	$/ckg, 100 index	% Change
1990	$73.58		$161.50	
1991	$66.06	-10%	$145.64	-10%
1992	$57.17	-13%	$131.84	-9%
1993	$61.32	7%	$151.93	15%
1994	$53.96	-12%	$146.93	-3%
1995	$56.59	5%	$151.97	3%
1996	$75.25	33%	$190.04	25%
1997	$73.11	-3%	$188.27	-1%
1998	$47.01	-36%	$125.25	-33%
1999	$46.31	-1%	$125.29	0%
2000	$60.00	30%	$164.55	31%
2001	$61.45	2%	$177.81	8%
2002	$46.29	-25%	$140.90	-21%
2003	$53.93	17%	$140.27	0%

Notes:

1. The U.S. prices are from the various sources that have been used to formula Ontario market hog prices in U.S. dollars.
2. The Ontario prices are the calculated yearly average price for all market pigs in Canadian dollars.

Figure 1. The U.S. and Canada hog cycle (1994 to 2004).



The above graph shows the yearly percentage change in the combined U.S. and Canada figures for:

- the number of pigs slaughtered
- the breeding herd inventory
- the various U.S. prices that have been used in the Ontario base formula

The graph utilizes the data that is shown in Tables 1, 2, and 3.

Table 4. Price conversion chart.

Ontario Market Hog Price ($/ckg, 100 index)

US$ Future	Canadian Dollar Value							
	$0.64	**$0.66**	**$0.68**	**$0.70**	**$0.72**	**$0.74**	**$0.76**	**$0.78**
$80	$227.94	$221.03	$214.53	$208.40	$202.61	$197.14	$191.95	$187.03
$78	$222.24	$215.51	$209.17	$203.19	$197.55	$192.21	$187.15	$182.35
$76	$216.54	$209.98	$203.81	$197.98	$192.48	$187.28	$182.35	$177.68
$74	$210.85	$204.46	$198.44	$192.77	$187.42	$182.35	$177.55	$173.00
$72	$205.15	$198.93	$193.08	$187.56	$182.35	$177.42	$172.76	$168.33
$70	$199.45	$193.40	$187.72	$182.35	$177.29	$172.50	$167.96	$163.65
$68	$193.75	$187.88	$182.35	$177.14	$172.22	$167.57	$163.16	$158.97
$66	$188.05	$182.35	$176.99	$171.93	$167.16	$162.64	$158.36	$154.30
$64	$182.35	$176.83	$171.63	$166.72	$162.09	$157.71	$153.56	$149.62
$62	$176.65	$171.30	$166.26	$161.51	$157.03	$152.78	$148.76	$144.95
$60	$170.96	$165.78	$160.90	$156.30	$151.96	$147.85	$143.96	$140.27
$58	$165.26	$160.25	$155.54	$151.09	$146.90	$142.93	$139.16	$135.60
$56	$159.56	$154.72	$150.17	$145.88	$141.83	$138.00	$134.37	$130.92
$54	$153.86	$149.20	$144.81	$140.67	$136.76	$133.07	$129.57	$126.24
$52	$148.16	$143.67	$139.45	$135.46	$131.70	$128.14	$124.77	$121.57
$50	$142.46	$138.15	$134.08	$130.25	$126.63	$123.21	$119.97	$116.89
$48	$136.76	$132.62	$128.72	$125.04	$121.57	$118.28	$115.17	$112.22
$46	$131.07	$127.09	$123.36	$119.83	$116.50	$113.35	$110.37	$107.54
$44	$125.37	$121.57	$117.99	$114.62	$111.44	$108.43	$105.57	$102.87
$42	$119.67	$116.04	$112.63	$109.41	$106.37	$103.50	$100.77	$98.19
$40	$113.97	$110.52	$107.27	$104.20	$101.31	$98.57	$95.98	$93.51
$38	$108.27	$104.99	$101.90	$98.99	$96.24	$93.64	$91.18	$88.84
$36	$102.57	$99.47	$96.54	$93.78	$91.18	$88.71	$86.38	$84.16
$34	$96.88	$93.94	$91.18	$88.57	$86.11	$83.78	$81.58	$79.49
$32	$91.18	$88.41	$85.81	$83.36	$81.05	$78.86	$76.78	$74.81
$30	$85.48	$82.89	$80.45	$78.15	$75.98	$73.93	$71.98	$70.14
$28	$79.78	$77.36	$75.09	$72.94	$70.92	$69.00	$67.18	$65.46
$26	$74.08	$71.84	$69.72	$67.73	$65.85	$64.07	$62.38	$60.78
$24	$68.38	$66.31	$64.36	$62.52	$60.78	$59.14	$57.59	$56.11
$22	$62.68	$60.78	$59.00	$57.31	$55.72	$54.21	$52.79	$51.43
$20	$56.99	$55.26	$53.63	$52.10	$50.65	$49.28	$47.99	$46.76

Note:

1. Formula is US$ future times 1.86 divided by the Canadian dollar value divided by 1.02.

MANURE AS A PLANT NUTRIENT

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ABSTRACT

There are many uses for manure, each dependent on the structure of the operation. The most common use for manure is a nutrient supply for plants. Manure, used as a fertilizer, can be cost efficient and feasible when the proper management techniques are implemented. The tools and techniques needed in order for manure to serve this purpose will be discussed, along with their challenges.

INTRODUCTION

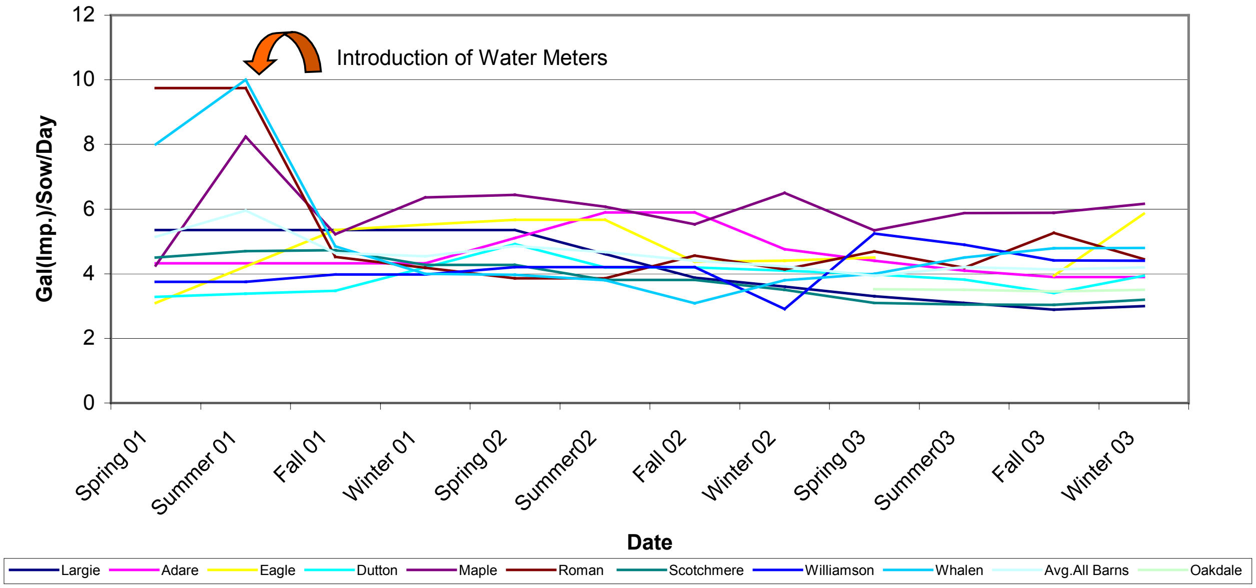
Manure is a bio-product that should be considered as an asset. Manure can be used as a fertilizer, converted to make gas, electricity, compost, recycled into re-useable water or an organic fertilizer. Every operation has different potential uses for manure, depending on their individual operations. Decisions on how best to utilize the manure produced by your operation and feasible solutions can be found within the organization, Advance Manure Management Technologies for Ontario (AMMTO). AMMTO tests and provide ratings on various manure technologies.

The most economical use for Premium Pork, is to utilize manure as a fertilizer. The highly diluted nature of sow manure (0-2% dry matter), the most common manure in our Canada operations makes the choices somewhat limited for the 85,000,000 gallons of manure produced each year. This highly diluted aspect of sow manure encourages continual discovery to economize on manure application. This includes optimum nutrient utilization, water management, transportation, and minimizing manure production.

WATER CONSUMPTION

The amount of manure produced is directly correlated with water usage. Premium Pork has installed water meters in farrowing and gestation rooms in all of their sow barns (Figure 1). Targets are set at 5.5 imp.gal/sow/day in farrowing and 2.42 imp.gal/sow/day in gestation based on the National Swine Water Consumption Guidelines. Timers, regulators and manifolds, along with proper management, are leading the company to reach the appropriate guidelines.

Figure 1. Gallons/sow/day of manure in Premium Pork sow barns (Ontario).



UTILIZING THE NUTRIENTS

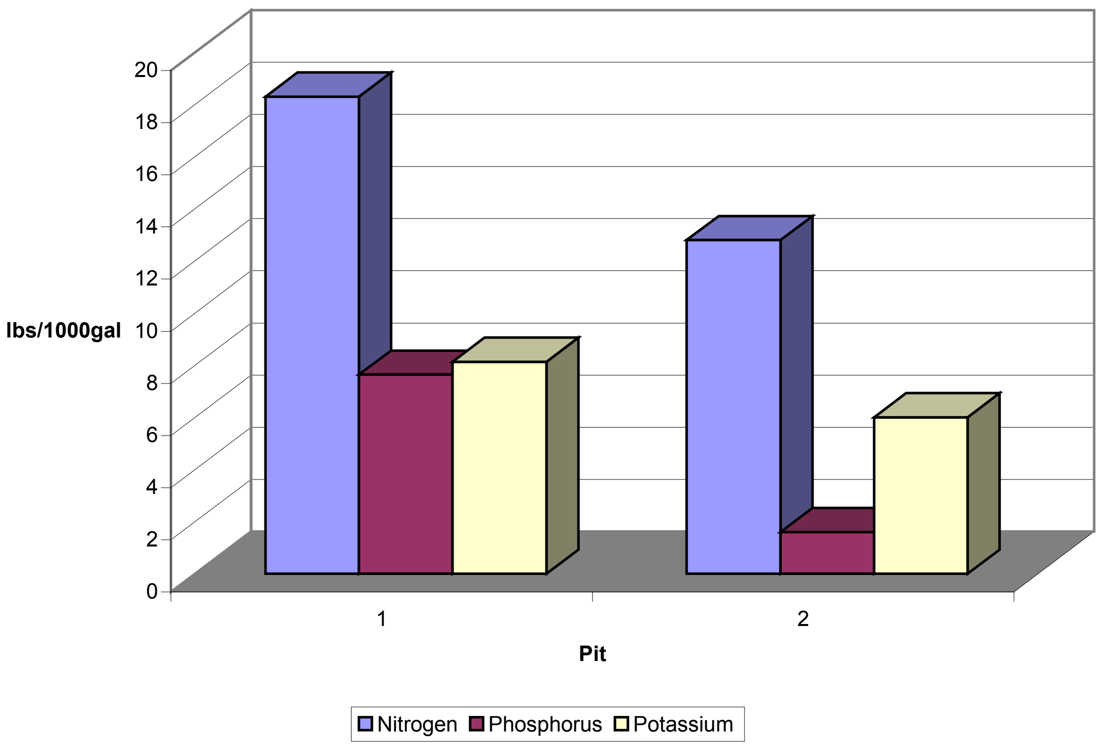
Benefits of manure include not only the nutrients N, P, K, but also, micro-organisms and organic matter. An average manure application has an economic value of $50.45/ac. A great tool in utilizing your nutrients to their fullest potential is the pre-nitrogen test. This soil-sample test is performed after you plant your corn crop, usually May/June, and based on the lab results the NH3 rate can be adjusted accordingly. This allows you to properly optimize your nutrient application economically and environmental. Experiments have shown that the timing of planting has a greater effect on profitability than the value of the manure when post-poning the planting date. A study was conducted in which one field did not receive manure but was planted 3 weeks earlier then the field across the road, which did receive manure. It concluded that the earlier field yielded 54 bu/ac more. The net result was $3.00/bu/corn x 54 bu/acre = $162/acre - $50.42/acre manure benefit = $111.55/acre.

The study concluded that it is better to get the crop into the ground early as opposed to holding off planting until the manure is spread if possible. A solution could be to plant the crop at the optimum time and then drag line over the planted crop. The hose does not seem to jeopardize the seed bed, and no major crusting appears to occur.

REDUCING TRANSPORTATION COST

Newer barns are equipped with the primary/secondary pit overflow. In this system, the manure runs from the barn to the primary pit. Once the primary pit is close to full, it flows over to the secondary pit near the top. This leaves highly diluted manure in the secondary pit with low nutrient values, and highly concentrated manure in the primary pit (Figure 2). In situations where there are fields varying in distance from the barn, the highly concentrated manure would be transported to the far land base and the land surrounding the barn would receive a higher application rate of manure from the secondary pit, as the Nutrient Management Plan allows.

Figure 2. Average N, P and K levels in pit 1 and in pit 2.



CONCLUSIONS

Manure as a fertilizer is a valuable nutrient within the confines of a proper agronomic setting when the proper management tools and techniques are implemented. Economic value and cost savings can be realized. New manure technologies will continue to be offered and are looked at with hope and optimism.

In the interim the highest and best use for manure in Premium Porks sow units is to employ it as a crop nutrient and return it back to the soil from whence it came from. Manure is an integral part of the created circle of life.

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