Final Report

Investigation Of Manure Production In Typical 3-Site Hog Facilities

Project #97/03

Submitted to:
Ontario Pork

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Executive Summary - Update August, 1999

In a 12-month period beginning in the spring of 1998, a study was initiated to examine the impact of wet/dry feeders on manure production, manure nutrient levels, and water use in feeder pig barns. This type of feeder is a popular choice in feeder barns. In addition, many of the recently-built feeder barns have been associated with three-site pig production. Manure samples were collected every second month from 21 farms. More detailed information was gathered for 17 of the farms. By studying water needs, feed inputs, numbers and weights of pigs entering and leaving the barns, manure production and manure nutrient levels, the following conclusions were reached:

1. The average water requirement for the wet/dry feeder barns was 5.54 L/pig/day, which was significantly less than the 7.92 L/pig/day average for the dry feeder barns. This represents a 30% reduction in water used.
2. The average amount of water needed to produce one kg of weight gain was 7.01 L for the wet/dry feeder barns and 9.86 L for the dry feeder barns. These numbers were significantly different.
3. Among the wet/dry feeder barns, there was no significant difference in water use per pig per day for the barns that had extra waterers in the pen (fixed nipples or swinging nipples) vs the farms with no extra waterers.
4. Water use varied over the year, with highest demand typically in the warm months (June, July, August, September).
5. Average manure production for the wet/dry feeder barns was 3.24 L/pig/day and for the dry feeder barns was 4.03 L/pig/day. Even though it appears the manure production for the wet/dry feeder barns was 20% less, the difference was not statistically significant. There was a great deal of variation from one farm to the next.
6. The amount of manure produced per kg of weight gain was 3.83 L for the wet/dry feeder barns and 5.21 L for the dry feeder barns. These numbers were not significantly different.
7. The dry matter content of the manure averaged 6.42% for wet/dry feeder barns and 3.43% for dry feeder barns. Much of the difference was due to the manure storage type - uncovered storages are subject to large amounts of added precipitation, which proved to significantly influence the manure dry matter content.
8. There was a great deal of variation among farms. For the wet/dry feeder barns, the average Nitrogen content of the manure was 0.65%. However, the highest average farm value was 1.05% and the lowest was 0.27%. The range in manure dry matter values for the wet/dry feeder barns was 3.01% to 11.11% (averages for 14 farms).
9. Due to variability among farms of the same feeder type, it appears there is still no good substitute for farmers collecting manure samples for analysis when carrying out nutrient management plans.
10. This study has helped to demonstrate reductions in manure production that are possible with wet/dry feeder barns and with dry feeder barns.

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1.0 Introduction

New technologies, especially newer designs of feeders in hog finishing barns, have the potential to result in lower volumes of manure that must be stored, with a proportionally higher nutrient concentration. Since manure storage represents a major cost for Ontario swine producers ($20,000 to $50,000 would be a common range for uncovered storages), we must attempt to size these storages as accurately as possible. This is the final report for Project #97/03, an investigation into the effect of wet/dry feeders on manure volumes produced, and manure nutrient concentrations in typical 3-site facilities on southern Ontario swine farms. The study has been conducted for Ontario Pork by Ridgetown College, University of Guelph with assistance from staff of the Ontario Ministry of Agriculture and Food and Rural Affairs (OMAFRA).

2.0 Background

2.1 Sizing of Manure Storages - Manure storage sizing in Ontario is based on research data from studies carried out more than 30 years ago. The approach has been to use these numbers representing the actual manure production, then increase the value by about 40% to account for dilution liquid, to come up with a required storage volume. Storage numbers based on these original estimates have been included in a variety of references used in Ontario over the past several years - e.g. The Canadian Farm Building Code (NRCC, 1977), The Canada Animal Manure Management Guide (Agriculture Canada, 1979), and Sizing of Manure Storages (Fleming, 1983).

There has been some attempt to verify that the numbers are accurate. A study by Bradshaw and Fleming (1981) looked at actual manure production on 14 swine farms. The actual measured manure production from the farms was compared to the predicted production. The average of these numbers was slightly higher than the predicted value and it appeared that there was no justification for changing the design numbers. However, the actual production ranged from as low as 36% of the predicted volume to a high of 236% of what was predicted.

The main cause of variation in storage volumes is the amount of dilution liquid that enters the storage. In their reference material, the American Society of Agricultural Engineers takes a different approach to sizing (ASAE, 1993). Manure production values are given, with no attempt to estimate the dilution liquid, and subsequently, the actual storage needs. There is far less variation from farm to farm in the actual production of feces and urine, as it is closely related to the weight of the animal. Based on ASAE data, for every 1000 kg of pig live animal mass, 84 kg of manure is produced daily (this is equivalent to 5.4 L/day for a 64 kg pig) at 13.1% dry matter. Actual manure samples submitted to labs in Ontario give a better idea of what is coming out of manure storages. The average nutrient concentrations of 359 swine liquid manure samples are: 0.37% N, 0.11% P, 0.16% K. The dry matter content average is 3.5% (OMAFRA 1999). This low dry matter content suggests that a considerable amount of dilution liquid has been added to the manure through some means.

Dilution liquid can be traced to several sources, including:

a) In the barn - washwater, leaking waterers, spray cooling systems;

b) Outside - direct precipitation, surface runoff into the storage, and drifting snow.

In the Bradshaw and Fleming study (1981), this variation in the addition of dilution liquid was identified as a main factor in the variability of total manure production. The "Outside" sources are relatively easy to predict. There are standard procedures for dealing with these. Of the "In the barn" sources, leaking waterers pose the biggest design problem (including actual leaks due to either design problems or wear, and spilled water resulting from animals playing with water nipples, etc.). One of the developments in recent years that could have a dramatic impact on the amount of this spilled water is the wet/dry feeder. Any leaking water from the waterers falls into the feeder and therefore does not enter the manure collection system.

2.2 Water Requirements - The key to variations in manure storage volumes, then, is water - both precipitation and supplied water. Water is required to produce new tissue in growth or pregnancy, produce milk and compensate for losses through respiration and evaporation and elimination of waste. Pigs obtain water from (1) consumption, (2) feed and (3) from the breakdown of carbohydrate, fat and protein. Water is lost by respiration, evaporation, defecation and urination. Water requirements are increased by high ambient temperature, fever, diarrhea and lactation. Pigs lose water vapor more by respiration than evaporation.

Swine water needs are variable. Access to waterers, seasonal temperatures, food mineral content, incidence of disease, dust and air dryness must all be considered. The common recommendation is that there be one waterer for every ten feeder pigs (Aker 1991). Finishing pigs in the weight range of 34 to 90 kg drink between 4.5 and 7.3 L/day of water (Agriculture Canada 1988). As the temperature increases, so does water consumption.

2.3 Wet/Dry Feeders - New hog-feeder technology promises to reduce the potential for spilled water in swine barns. This would provide a significant reduction in operating and capital costs by :

1) trimming costs for clean water supply (particularly where supply is metered)
2) reducing wear on transfer equipment (pumps, valves, tankers)
3) curbing size of storage structures to be built and maintained
4) cutting back on trips to the field to recycle farm-generated crop nutrients
5) minimizing soil compaction (less loading), and
6) increasing nutrient concentration (and value) of manure.

This decrease in manure volume is also likely to affect odour levels and could affect the potential to contaminate surface water or groundwater. The pressure to empty manure storages in marginal field conditions is eased. Timeliness in application for crop needs is improved, resulting in more efficient nutrient use and potentially lower cost for commercial fertilizers.

Current standards for sizing manure storages are based on the number of animals, daily manure production, desired storage in days as well as anticipated extra water. However, the water consumption reductions from wet/dry feeders have not been measured under typical Ontario management systems.

In a conventional dry feeding system, pigs typically eat from a feeder containing “dry” feed. The waterer is located in a separate area of the pen. Figure 1 shows an example of a dry feeder. With wet/dry feeders, the waterers are mounted in the feeder, so that water drops into the feed and is consumed by the pigs. An example of a wet/dry feeder is shown in Figure 2. A third, less common, feeding system option is “liquid feeding”. Liquid feeders have the advantage of minimizing feed waste and significantly reduce dust in the feeding area. Liquid feeding involves providing the pig with a known mixture of feed and water. Its consistency can be altered to the pigs’ liking or equipment capabilities.

Figure 1 Dry feeder

OMAFRA (1992) suggests that a 30 percent reduction in storage design volumes could be assumed where wet/dry feeders are used. Anecdotal evidence suggests manure production may be reduced by as much as half, depending upon the operation. Indeed, farmers have noted that liquid manure may become so “stiff” that older equipment may be unable to pump it from the short-term or long-term storages. In addition, older designs of barn gutters may not drain efficiently, requiring the *addition* of new water.

Gro Master (1999) advertizes that “Crystal Spring” wet/dry feeders can reduce water use by up to 50% compared to dry feeders. Researchers at Kansas State University compared three commercially-available feeders on 300 finishing hogs. Those used in the study included a single-hole wet-dry feeder (Crystal Spring) versus a dry two-hole feeder (Aco) and a dry round nine-hole feeder (Osborne). During the summer months, the wet/dry feeder water consumption was reduced by 42% with little effect on average daily feed intake. Pigs fed from the wet/dry feeder had a 7.7% better feed efficiency during both summer and winter than pigs fed from either of the other two dry feeders. However, water use was only slightly less for pigs on the wet/dry feeder during the winter months and producers were advised to consider the cost of different types of feeders when making their decisions (Luce 1999).

Figure 2 One of several types of wet/dry feeders

Japanese researchers studying five feeder types (including two wet/dry types) determined that feeder type had no effect on average daily gain. Feed intake increased from 5 to 8% on wet/dry feeders. Water intake varied according to the type of wet/dry feeder resulting in a water-saving effect of 3 to 31% (Miyawaki et al, 1998).

The issues of growth and weight gain may be crucial to the general adoption of wet/dry feeders, regardless of manure volume reductions and benefits promised. Not all researchers are agreed upon universal feed conversion efficiencies. One researcher, while not examining water consumption or waste noted a 6 to 9% feed conversion efficiency improvement in wet/dry feeder groups (Miyawaki et al, 1996). Pluske (1996) noted piglets weaned at 30 days, feeding at single-space wet/dry feeders had a lower growth rate over the next 28 days than piglets fed from two types of dry feeders. They indicated that the piglets may have found the accumulated porridge-like “gruel” in the bottom of the feed tray to be unpalatable. Their hypothesis that wet/dry feeders would increase piglet growth rate after weaning due to increased feed consumption was not supported since performance was similar between feeder types.

2.4 Three-site Swine Production - Many of the swine facilities built in the last decade have been based on 3-site production. The entire operation is located at a total of three sites - e.g. three farms, perhaps owned by three different farmers. This practice offers advantages in biosecurity and specialization. All breeding animals are located at one site, weaner pigs at a second site and feeder pigs at the third. Relatively speaking, the greatest amount of manure is generated at the feeder operation and it is there that the wet/dry feeders are being used increasingly.

2.5 Nutrient Management - There is a major effort in Ontario to adopt nutrient management planning as a general farm practice, especially on livestock farms. This involves determining crop nutrient needs and applying nutrients from manure or other sources to supply those nutrients. It aims to avoid over-application of nutrients, which can lead to environmental problems. In order to make the most efficient use of nutrients, livestock farmers must know the nutrient content of the manure. Default values in the existing NMAN computer program do not distinguish which samples are from barns with wet/dry feeders. However, as the moisture level of the manure is reduced, it follows that the nutrient concentration will be higher (the pigs still produce similar amounts of feces and urine).

3.0 Objectives

1) To measure manure production in existing new 3 site swine finishing facilities and compare the results to existing storage sizing standards - especially examining the impact of wet/dry feeders.
2) To propose changes to sizing specifications, if warranted.
3) To measure manure nutrient concentrations and determine the effect on nutrient management plans.

4.0 Experimental Procedure

4.1 Site Selection - Study criteria required that test operations have several common elements for inclusion in the study:

1. 3-site finishing barns (with wet/dry feeders) must be recently completed.
2. Operators willing to record manure levels, inventory feed, water consumption, livestock movements and shipping weights on a monthly basis for a year.
3. Provide access to manure storages for regular sampling.
4. Record amounts of manure removed from storages.
5. Complete a survey providing operational details.

Initially OMAFRA and agri-business were canvassed to suggest cooperators. Eventually Ridgetown College staff made contacts and arranged for installation of water meters (where necessary) and uniform record keeping. A total of 23 operators agreed to participate, representing 26 barns. Conventional feeders, wet/dry feeders and one liquid feeding system are represented in the study.

4.2 Collection of Farm Data - A preliminary questionnaire was composed and distributed. This organized farm information into various categories, describing barn type and capacity, production system (batch or continuous) watering system, feeding system, and manure storage descriptions and capacities. These were returned early in the study.

Farm data sheets were created to record and organize farm data on a monthly basis. These were left with the farmer to record the consumption and production information. There were four major divisions :

A - water record for water meter readings and date of reading
B - record of dates, weights and numbers of all pig movement in and out
C - records of all feed inputs, dates and weights, and
D - all manure storage(s), measurements and dates.

Farmers were contacted in November and December 1998 to check on the progress of data collection. A sample of each form is included in the Appendix.

4.3 Sample Collection and Analysis - Each site was visited six times for manure sample collection, between mid-July, 1998 and March 1999. During the visit it was noted if the tank had been recently agitated or emptied. At each site, a composite sample was taken from the main storage using a clean one litre plastic bottle in a stainless steel sampler. The plastic bottle filled as it was moved up and down through the stored manure. Three individual samples were composited in a clean single-use plastic bag in a two-litre plastic bucket. After being thoroughly mixed, a representative sample was put into a labeled 500 mL plastic sample bottle. All sampling equipment was cleaned using a rinse-soap-rinse regimen prior to departing for the next sample site. Measurements of manure storage levels were recorded during the site visits. For transport, samples were placed in a cooler with artificial ice and then transferred to a refrigerator. Samples were then taken to the University of Guelph Soil and Nutrient Laboratory for analysis. Samples were analyzed for total N, P, K, NH_4-N, pH, and dry matter.

Three operators insisted on collecting the in-barn samples themselves in order to minimize the chance of spreading disease among the farms. Clean overalls, disposable latex gloves and plastic overshoes were used at all sites.

4.4 Determining Water Use - Reconditioned, re-calibrated flow meters were purchased (from the City of Chatham) and distributed to those farms that did not have a water meter in the study barn. The farmers performed the installation at the water line serving the barn. The meters were manufactured by TriDent (Neptune Model) and were either designed for either 3/4 inch or one-inch water lines. Two meters became defective early in the project and these were replaced. Six of the 21 sites had their own water meters already installed and these were assumed to be calibrated and accurate. Based on monthly water meter readings, total volumes of water for the barns were calculated. For each site, one drinking water sample was collected and tested for nitrates, pH, and conductivity as a means to screen out farms with water quality concerns.

4.5 Determining Manure Production Volumes - To calculate manure production volumes, it was necessary to account for precipitation into the uncovered storages. Of the 21 sites, six had uncovered storages. None of the affected farmers supplied precipitation data, so records from nearby farms were used (OMAFRA rainfall recording network). Since these did not cover winter precipitation, long-term average data were used to cover the four-month winter period (Ridgetown College weather records - M. MacAlpine; Environment Canada, 1992; Smith, 1999). The aim was to remove precipitation as a source of variability between farms. No evaporation was calculated for the uncovered storages.

5.0 Results and Discussion

5.1 Site Characteristics - In total, about 75 farmers were contacted to come up with 26 sites. The 26 sites were soon reduced to 21, for various reasons. The final group completed and returned the farm survey sheets, documenting: number of pigs, size of manure storage, barn layout, feeding system details, etc. The farmers also filled in monthly log sheets to keep track of manure storage levels, water meter readings, barn inventories and feed used. Manure samples were collected from the 21 storages.

A sudden drop in pork prices during the past year led to changes on some of the study farms. Some farm workers were laid off, leaving less time for the farmer to devote to the additional work of this study.

On one farm, the roof blew off the barn in a summer storm resulting in very high mortality rates and a low average shipping weight. Another had a disease outbreak. This farmer did not complete the monthly records. In another case, modifications to the watering system were made halfway through the study - fixed waterers were replaced with swinging units. Unfortunately, vital manure measurement notes were misplaced during the renovations.

All farms had record-keeping methods reflecting their management style and farm needs. While standardized report forms were distributed, each case required several contacts for interpretation of provided information. Some provided data on a day to day basis, while others made a single entry to cover a whole year's manure production or water consumption. All of these numbers were reviewed by staff and confirmed for accuracy.

The timing of the study proved to be a problem for some farmers - final data sheets were needed during the busy spring season. These reports were often late in arriving and one farmer was unable to complete his farm data collection by the due date.

By the end of the study, complete sets of numbers were available for 17 of the 21 sites. Manure test results were available for all 21 sites.

5.2 Pig Numbers and Weights - The 12 farms with wet/dry feeders ranged in size from 550 to 4,200 pig spaces, with an average of 1,300 spaces per operation. The four dry feeder barns ranged in size from 425 to 1,550 pigs, averaging 865.

The ranges of weights of pigs were 27.2 to 105.0 kg for the dry feeder barns and 31.2 to 103.9 kg for the wet/dry systems (including Site12, where pigs were shipped early following roof damage). Average pig weights for the study were 67.6 and 66.1 kg for "wet/dry" sites and "dry" sites, respectively. The site with liquid feeding handled pigs in the weight range of 25.5 to 107.7 kg.

Death losses are a part of business for hog producers. When calculating weight gains, allowance was made for animals that died partway through the process. If the information was provided by the farmer, that number was used. However, where the number was missing, death loss was assumed to be 3%, at an average weight of 60 kg (Bancroft 1999).

Of the 17 sites where detailed records are available, 12 use an all-in, all-out management system (where rooms are loaded all at once, and each room is empty for a brief period to allow for disinfection). The remaining five sites use a continuous system, where animals are arriving and leaving continuously.

Only one of the farmers reported the monthly barn inventory numbers - the farmers felt it would require too much effort to transfer their numbers into the reporting format that we had set up. As a result, the "design barn capacity" is used for some of the calculations found in the following sections. Other calculations make use of actual weight gains (difference between weights out vs. in). In general, the farmers felt that the actual numbers of animals in the barn at any time was close to what the barn was designed to hold.

In order to verify that the design barn capacity numbers were accurate, calculations were made to create several "checks". One of these is the average space per pig in the study barns, using the barn dimensions and the barn capacity numbers. The results of this calculation are shown in Table 1, Line L. Barns ranged from 0.64 to 1.10 m^2 per pig. This seems reasonable, given that the pig needs about 0.6 m^2 of actual pen space and allowance must be made for such items as utility rooms, offices, feed rooms, walkways and wall thicknesses (depending on the situation).

The average weight gain, in kg/pig/day is shown in Line Q of Table 1. Most farms were in the range of 0.60 to 0.80 kg/pig/day. There did not appear to be a difference from the wet/dry feeders to the dry feeders. However, the liquid feeder barn had the highest value at 0.99 kg/pig/day.

Table 1 Summary of Selected Data for All Farms - Part A: Wet/Dry Feeder Barns

Wet/Dry Feeders													
Site Number:	1	4	8	10	11	12	5	6	2	3	9	13	**Avg.**
A : Water consumed (m^3)	4,025	1,938	1,791	2,008	2,014	1,203	7,699	2,650	1,502	2,040	1,866	2,678	**2,618**
B : Pig movement net out (t)	493	266	190	329	396	275	1,385	309	202	268	421	265	**400**
C : Feed consumed (t)	1,477	643.0	750	778	826	753	3,070	1,165	284	820	740	803	**1,009**
D : Manure produced (m^3)	1,038	1,272	1,066	1,232	1,433	863	8,670	691	856	727	1,319	1,158	**1,694**
E : Pig spaces in study barn	1,600	1,000	950	1,100	1,000	550	3,697	1,500	800	1,050	900	1,000	**1,262**
F : Precipitation deducted (m^3)	647	0	120	0	0	0	0	637	0	0	0	0	
G : Feed conversion - C / B (kg/kg)	3.0	2.4	3.9	2.4	2.1	2.7	2.2	3.8	1.4	3.1	1.8	3.6	**2.70**
H : Water (kg) / # spaces / day	6.3	5.7	5.3	5.0	5.5	6.0	5.7	5.0	5.1	5.4	5.4	6.0	**5.54**
I : Manure (L) / # spaces / day	1.6	3.8	3.2	3.1	3.9	4.3	6.4	1.3	2.9	1.9	3.8	2.6	**3.24**
J : Total # Pigs out	6,183	3,078	2,544	4,139	3,891	2,672	13,288	5,736	2,840	3,221	4,094	3,192	**4,573**
K : Days	400	338	355	366	366	365	365	354	365	359	381	373	**366**
L : Space (m^2 / pig)	0.94	0.76	0.81	1.10	0.81	0.90	1.02	0.91	0.64	0.84	0.71	1.04	**0.87**
M : Manure / Weight Gain - D / B (kg/kg)	2.10	4.78	5.61	3.74	3.62	3.14	6.26	2.23	4.23	2.71	3.13	4.38	**3.83**
N : Water / Weight Gain A / B (kg/kg)	8.16	7.29	9.42	6.09	5.09	4.37	5.56	8.56	7.42	7.62	4.43	10.12	**7.01**
O : Average weight in (kg)	29.59	24.04	26.84	27.02	31.75	55.00	25.19	29.00	30.29	25.00	45.36	25.81	**31.24**
P : Average weight out (kg)	109.54	110.45	105.89	105.55	101.70	102.98	104.25	82.97	101.68	108.18	104.62	108.70	**103.88**
Q : Average weight gain (kg/pig/day)	0.77	0.79	0.60	0.81	0.74	0.64	0.78	0.58	0.69	0.71	0.71	0.71	**0.72**
Storage Type	Open	Covered	Open	Covered	Covered	Covered	Covered	Both	Covered	Covered	Covered	Covered	
Water Supply Modifications	none	none	none	none	none	none	swing	swing	fixed	fixed	fixed	fixed	

Table 1 Summary of Selected Data for All Farms - Part B: Liquid and Dry Feeder Barns

	Liquid		Dry Feeders				
Site Number:	15		16	23	21	20	**Average**
A : Water consumed (m^3)	4,830		1,850	1,543	2,082	1,788	**1,816**
B : Pig movement net out (t)	642		162	156	348	148	**203**
C : Feed consumed (t)	1,709		374	405	947	291	**504**
D : Manure produced (m^3)	3,629		823	1,072	1,769	560	**1,056**
E : Spaces in study barn	1,800		850	425	1,550	634	**865**
F : Precipitation deducted (m^3)	0		560	0	364	410	
G : Feed conversion - C / B (kg/kg)	2.7		2.3	2.6	2.7	2.0	**2.40**
H : Water (kg) / # spaces / day	7.4		8.0	8.3	3.6	11.7	**7.93**
I : Manure (L) / # spaces / day	5.5		3.5	5.8	3.1	3.7	**4.03**
J : Total # Pigs out	7,855		1,886	1521	4,645	1,202	**2,314**
K : Days	365		273	435	369	233	**328**
L : Space (m^2 / pig)	1.00		0.94	1.05	0.89	0.93	**0.95**
M : Manure / Weight Gain - D / B (kg/kg)	5.66		5.08	6.88	5.08	3.79	**5.21**
N : Water / Weight Gain A / B (kg/kg)	7.53		11.43	9.90	5.98	12.11	**9.86**
O : Average weight in (kg)	24.54		24.95	25.00	30.71	28.00	**27.16**
P : Average weight out (kg)	107.69		105.52	102.43	105.65	106.23	**104.96**
Q : Average weight gain (kg/pig/day)	0.99		0.65	0.64	0.61	0.64	0.64
Storage Type	Covered		Open	Covered	Both	Both	
Water Supply Modifications	none		fixed	swing	fixed	fixed	

5.3 Water Use - In order to compare water use from one farm to the next, two relationships have been calculated:

A) The average amount of water entering the barn per day per pig (L/pig/day) is the first of these. This includes all water that flowed through the water meter - water used for drinking, washing and spilled or leaking water. All values and averages for each feeder type are shown in Line H of Table 1. The number of pigs used for this calculation is the Design Barn Capacity (since the "actual barn inventory" numbers were unavailable). The average for the wet/dry feeder barns was 5.54 L/pig/day which was significantly less ($P = 0.05$) than the average for the dry feeder barns, which was 7.92 L/pig/day. In other words, on a "per pig" basis, the wet/dry feeder barns used 30% less water than the dry feeder barns. The liquid feeder barn average was 7.35, which was not significantly different from either of the other two systems.

B) The average amount of water needed to produce one kg of weight gain is shown in Line N of Table 1. This is calculated by dividing the total water consumption (Line A) by the total weight gain of the pigs (Line B). For the wet/dry feeder barns, the average was 7.01 L/kg, which was significantly different (using 95% LSD) from the average of 9.86 L/kg for the dry feeder barns. The liquid feeder barn average was 7.53 - also not significantly different from the other two.

Among the wet/dry feeder barns, a further breakdown of management types was possible. Six of the farms (Sites #1, #4, #8, #10, #11, #12) relied on wet/dry feeders as their only water supply for the pigs. On the remaining sites, the farmers had installed additional water nipples in the pens. At Sites #5 and #6, swinging waterers were used, while at Sites #2, #3, #9, and #13, fixed nipples were attached to the pen walls. The average values of water used for the three groups were 5.64, 5.35 and 5.49 L per pig per day, respectively. There was no significant difference between the three groups.

Only Site #9 reported using sprinklers for cooling during hot weather. Sites #16 and #23 also verbally confirmed using a sprinkler system, and others may also, but the data sheet did not specifically ask for this detail. These sprinklers would typically be on a timer and during hot weather would create a periodic shower in part of the pen, allowing the pigs to cool down. The numbers in Table 1 suggest that the spray cooling system did not add significantly to the total amount of water in the system for Site #9. Unfortunately, detailed volume and "running time" data were not available.

The other potential source of water directly into the manure storage is wash-water. Again, most operators did not specifically record this as an extra source of water, though evidence suggested that most of the group did some wash-down of pens once the pens were emptied. This practice helps reduce the potential for spread of disease. The typical system would consist of a high-pressure, low-volume cleaner, that would add a small amount of extra water to the storage.

Water use varied throughout the year. For some farms it was possible to calculate monthly average water needs. An example is shown in Figure 3, which gives water needs over the full year for Site #5. This site appears to be typical. Figure 3 demonstrates that the water needs are greater during the warmer months of the year, which was expected.

5.4 Manure Production and Nutrient Concentration - Table 1 summarizes manure

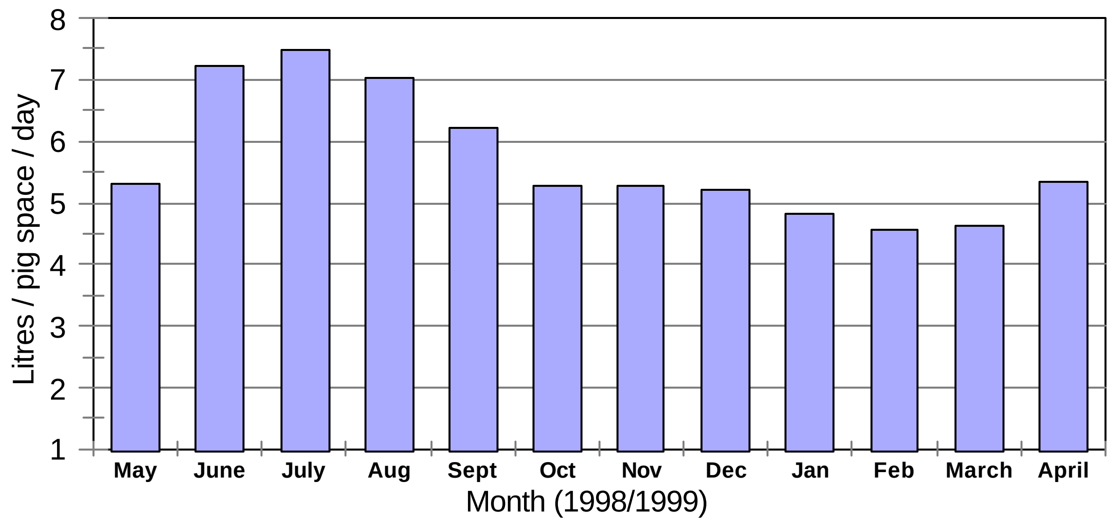

Figure 3 Monthly water consumption for Site #5

production information as reported by farm co-operators and offers additional measures of comparison. Farm information is arranged into three groups according to feeder type.

Total manure production volumes for each site are shown in Line D. Precipitation collected in uncovered manure tanks and earthen pits has been deducted from this number. The volumes of precipitation calculated are reported in line F. These amounts of precipitation range from a minimum of 16% (Sites # 8 and #21) to a maximum of 92% (Site #6) of the total manure production (excluding precipitation). To store and spread this collected precipitation constitutes a significant expense in comparison to the total manure storage and spreading costs. No evaporation has been factored in to these numbers, even though it is possible for evaporation to equal precipitation at least during the summer months.

The average manure production for the wet/dry feeder barns was 3.24 L/pig/day, compared to 4.03 for the dry feeder barns (5.5 L/pig/day for the liquid feeding barn). Even though it appears that manure production in the wet/dry feeder barns is only 80% of that in the dry feeder barns, there is enough variability from farm to farm (e.g. Standard Deviation = 1.4 for wet/dry feeder barns) that there is no significant difference in manure production between feeding systems ($P = 0.22$). In the wet/dry feeder barns, the three watering options were compared to see if one led to greater manure production levels. There was no significant difference in manure production per pig per day for the three watering systems. This came as somewhat of a surprise, as it seemed likely that the barns with fixed water nipples on the wall would have more spilled water than the systems where all water was supplied in the feeder.

The amount of manure produced per unit weight of meat production was calculated. Once again, these relationships were not significantly different between feeder types. The wet/dry feeder barns averaged 3.83 L of manure per kg of meat produced, compared to 5.21 and 5.66 for the dry feeder and liquid feeder barns, respectively.

Manure test results were available for all of the original 21 farms in the study. A summary of the test results, grouped by feeder type, is given in Table 2. The average Dry Matter concentration was expected to be higher for the wet/dry feeder barns. This proved to be the case, with a DM of 6.42% (SD = 2.5, max = 11.1, min = 3.0). This was significantly higher (P = 0.04) than the 3.43% for the dry feeder barns (SD = 1.4, max = 5.8, min = 2.3). For the liquid feeding barn, the average DM was 4.2%.

Table 2 Manure Test Averages

Farm Number	N (%)	P (%)	K (%)	NH4-N (mg/L)	DM (%)
Wet/dry feeders					
1	0.27	0.082	0.29	1339	3.56
12	0.70	0.334	0.31	2834	7.60
3	0.65	0.268	0.30	2282	9.44
4	0.61	0.143	0.26	3006	5.42
14a	0.35	0.104	0.21	1700	4.24
2	0.59	0.106	0.31	3611	3.78
5	1.05	0.472	0.51	3411	11.11
6	0.43	0.086	0.30	2733	3.01
8	0.63	0.182	0.32	3567	5.00
9	0.69	0.255	0.32	2713	5.74
10	0.91	0.248	0.45	5279	7.65
11	0.81	0.205	0.44	4728	5.87
13	0.72	0.232	0.36	3388	8.37
14b	0.68	0.278	0.32	2951	9.13
average	**0.65**	**0.21**	**0.34**	**3110**	**6.42**
Dry feeders					
16	0.31	0.049	0.17	1925	2.68
18	0.67	0.354	0.28	2961	5.82
23	0.31	0.045	0.12	2148	2.26
17	0.19	0.093	0.17	880	2.36
20	0.36	0.115	0.20	1894	3.19
21	0.33	0.079	0.27	1209	4.30
average	**0.36**	**0.12**	**0.20**	**1836.10**	**3.43**
Liquid feeding					
15	**0.46**	**0.113**	**0.26**	**2444**	**4.20**

It is important to note that precipitation was subtracted from total manure production to give a "Net" production value for the various calculations. However, in those cases where manure was stored in an uncovered storage, samples were collected from that storage and the large amount of extra dilution liquid had an impact on dry matter levels. For example, the average dry matter content of manure from covered storages was 6.47%, which was significantly higher than the value of 3.57% from the open concrete tanks. Looking only at the manure samples from the 14 farms with covered storages, the average DM for the 11 wet/dry feeder barns is 7.12%. This is not significantly higher than the average of 4.04% for the two dry feeder barns having covered storages.

The nitrogen content of the manure from the wet/dry feeder barns (average = 0.65%, SD =

0.21) was significantly higher than that in the dry feeder barns (average = 0.36%, SD = 0.16). This becomes important for farmers preparing nutrient management plans for their operations, who need an accurate assessment of available nutrients in manure.

Many farmers have become interested in treating manure to reduce odours and provide other benefits. The farmers in this study are no exception. Of the 17 sites with the most complete data, only six farms used no further manure treatment - an anaerobic storage held the manure until it was spread on the land. The remaining farms used one or more of the following: manure additives, feed additives having a specific effect on manure properties, or a floating windmill in the uncovered storage. Insufficient data were collected to show what, if any, effect these treatment technologies had on manure properties.

5.5 Feed

The feed conversion was calculated for each feeding system. This represents the amount of feed needed to produce a unit weight gain. As mentioned earlier, this was the focus of earlier research on wet/dry feeders. Averages for the three feeder types were 2.96 (kg feed per kg weight gain) for wet/dry feeders, 2.66 for liquid, and 2.40 for dry feeders. These averages were not significantly different. The study was not intended to be a detailed comparison of feed conversion values for different feeding systems. Several significant contributing factors were not well-documented - including the influence of genetics, nutrition, and the background herd health status.

Figure 4 gives a summary of inputs and outputs for the two main feeder types in the study. It is set up to show water and feed inputs and manure outputs per kilogram of meat produced. For those six sites with uncovered manure storages, the manure production number is based on the net manure after precipitation has been removed. At least part of the difference between inputs and outputs is due

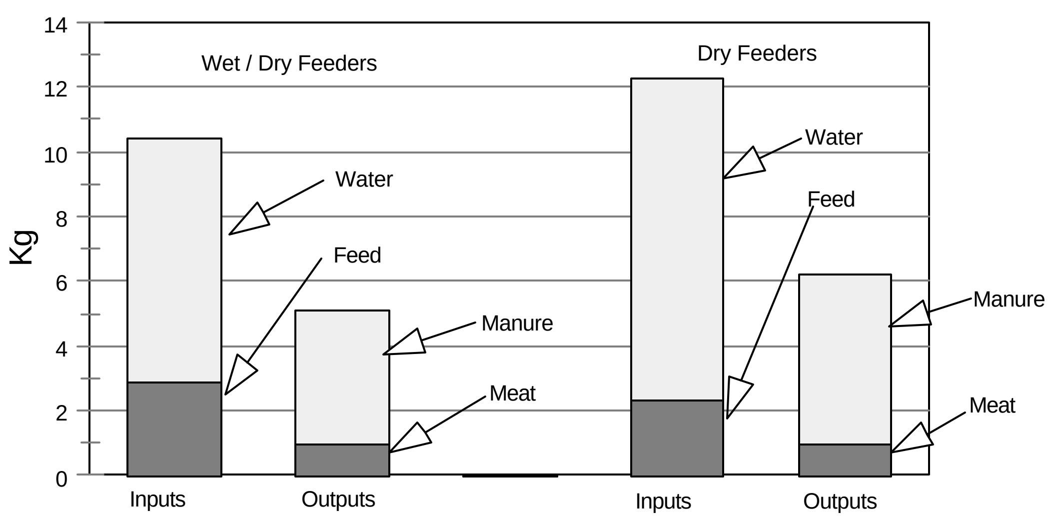

Figure 4 Comparison of Inputs and Outputs for wet/dry and dry feeders - i.e. inputs of feed and water and outputs of manure for every kg of meat produced

to moisture that is removed by the ventilation system. This includes respired moisture and moisture evaporating from the floor surface. According to Agriculture Canada (1988), at 24 °C , a ventilation system must remove 2.64 kg of moisture per day for a 62 kg hog. Based on an average weight gain per day of 0.70 kg (from the current study, Table 1, wet/dry feeders), the amount of moisture that is removed by the ventilation system per kg of weight gain is 3.8 kg (4.1 kg using the dry feeder average daily gain).

6.0 Summary and Conclusions

This project has attempted to develop design numbers for sizing manure storages on farms using wet/dry feeders with feeder pigs. Manure samples were collected every second month from 21 farms. More detailed information is available for 17 farms. By studying water needs, feed inputs, numbers and weights of pigs entering and leaving the barns, manure production and manure nutrient levels on various farms over a one-year period, the following conclusions have been reached:

1. The average water requirement for the wet/dry feeder barns was 5.54 L/pig/day, which was significantly less than the 7.92 L/pig/day average for the dry feeder barns. This represents a 30% reduction in water used.
2. The average amount of water needed to produce one kg of weight gain was 7.01 L for the wet/dry feeder barns and 9.86 L for the dry feeder barns. These numbers were significantly different.
3. Among the wet/dry feeder barns, there was no significant difference in water use per pig per day for the barns that had extra waterers in the pen (fixed nipples or swinging nipples) vs the farms with no extra waterers.
4. Water use varied over the year, with highest demand typically in the warm months (June, July, August, September).
5. Average manure production for the wet/dry feeder barns was 3.24 L/pig/day and for the dry feeder barns was 4.03 L/pig/day (after subtracting precipitation collected in uncovered storages). Even though it appears the manure production for the wet/dry feeder barns was 20% less, the difference was not statistically significant. There was a great deal of variation from one farm to the next (the Standard Deviation for the wet/dry feeder barns was 1.4).
6. The amount of manure produced per kg of weight gain was 3.83 L for the wet/dry feeder barns and 5.21 L for the dry feeder barns. These numbers were not significantly different.
7. The dry matter content of the manure averaged 6.42% for wet/dry feeder barns and 3.43% for dry feeder barns. Although this was significantly different, much of the difference was due to the manure storage type - uncovered storages are subject to large amounts of added precipitation, which proved to significantly influence the manure dry matter content.
8. There are many differences in management practices from one farm to the next. Even though it would appear that there are standard ways of raising feeder pigs, there is

enough variation among farms to make it difficult to draw any more specific conclusions about the impact of feeder type. Examples of other influences include herd genetics, feed nutrition, herd health status, differences in record-keeping, death losses, etc. For the wet/dry feeder barns, the average Nitrogen content of the manure was 0.65%. However, the highest average farm value was 1.05% and the lowest was 0.27%. The range in manure dry matter values for the wet/dry feeder barns was 3.01% to 11.11% (averages for 14 farms).

9. Due to variability among farms of the same feeder type, it appears there is still no good substitute for farmers collecting manure samples for analysis when carrying out nutrient management plans.
10. This study has helped to demonstrate reductions in manure production that are possible with wet/dry feeder barns and with dry feeder barns.

7.0 Technology Transfer

To inform the swine farmers of Ontario that this project was taking place, two articles were prepared. One appeared in the January/February edition of Pork News & Views '98 (pg 12). A project factsheet (attached to this report) was prepared for circulation at the Ontario Pork Congress, held in Stratford in June, 1998.

As manure test results became available, they were sent to the farmers in the study, along with summary data from other farms. A copy of this final report will be sent to all farmers in the study. A summary of the study results will be sent to the Swine Research Update (held in January). A paper proposal will be submitted to the Canadian Society Of Agricultural Engineering for their technical sessions in 2000. Design/sizing information will be incorporated into the Nutrient Management Computer program NMAN99, which is widely used in Ontario, and the manure storage sizing program, MSTOR. These programs are being revised and an updated version will be released in August.

8.0 Acknowledgments

The authors would like to acknowledge the contributions to the study of:

Don Hilborn - OMAFRA, for assistance in setting up the study and for incorporation of the results in to the Nutrient Management and Manure Storage Sizing computer programs;

The swine producers who participated in the study, who maintained interest and diligently recorded information even in the wake of a crippling price drop for their industry;

Ontario Pork and the Agricultural Adaptation Council (Agriculture and Agri-Food Canada), who provided the funding to allow this study to happen.

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10.0 Attachments

1. Project Factsheet. Investigation Of Manure Production In Typical 3-Site Hog Facilities

2. Farm Survey Sheet

3. Farm Data Sheet

Project Factsheet

Investigation Of Manure Production In Typical 3-Site Hog Facilities

Ron Fleming, P. Eng., Ridgetown College - University of Guelph

New technology, especially newer designs of feeders in hog finishing barns can result in lower volumes of manure that must be stored, with a proportionally higher nutrient concentration. Since manure storage represents a major cost for Ontario swine producers, we must attempt to size these storages as accurately as possible. For example, to store the manure from a barn to hold 1000 feeder pigs for a period of 250 days would need a tank about 90 feet diameter by 12 feet deep and would cost nearly $40,000 - based on *current* sizing standards.

Manure storage sizing in Ontario is based on research data from studies carried out more than 30 years ago. This includes an allowance for the dilution water that ends up in the manure storage - resulting from spilled water, wash water, and other sources. It **doesn't** take into account the reduced volume of spilled water that results from the use of wet/dry feeders. This volume reduction is quite significant on some farms, but has never been actually measured on a large number of similar farms.

Objectives - We recently received funding from Ontario Pork to carry out a year-long investigation on Ontario swine farms. The study aims:

1) To measure manure production in existing 3-site swine finishing facilities and compare the results to existing storage sizing standards - especially examining the impact of wet/dry feeders.
2) To propose changes to sizing specifications, if warranted.
3) To measure manure nutrient concentrations and determine the effect on nutrient management plans.

Manure production levels on farms using wet/dry feeders will be compared to production on farms using the more "traditional" styles of feeder.

The study involves at least 25 barns - keeping track of water inputs using water meters, measuring manure levels monthly, recording pigs sizes, feed inputs, and discovering the most appropriate formula for sizing manure storages. This study should be complete by the summer of 1999.

For more information, contact:
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phone: 519 674 1612
fax: 519 674 1600
email: rfleming@ridgetownc.uoguelph.ca
date: June 23, 1998

Swine Manure Production Study 1998-99

Ron Fleming (519-674-1612), Malcolm MacAlpine (519-674-1602),
Ridgetown College/University of Guelph

Name of Farmer: ____

Farm Name: ____

Mailing Address: ____

____

____

Location: **(eg. lot, concession, township)**

____

____

Phone: **(519)**____

Fax: **(519)**____

Email: ____

Farm number assigned for this study: _________

Questionnaire

These questions will help with a study to accurately measure on-farm manure production levels on farms using wet/dry feeders and to compare these to production on farms using the more “traditional” style of feeder. This series of questions should be filled in near the start of the study. This is information that is only needed once, unless there are major changes to the operation (e.g. new manure storage built). A separate series of sheets will be used to collect the monthly data on water use, feed use, sizes of pigs, manure production, manure spreading, manure sampling.

1. Is this a Grower/Finisher barn?

G Yes

G Yes - but it includes:____________________

____

G No - it houses: _________________________

____

2. What is the approximate capacity of the “study” barn? Number of animals = ________

3. Which best describes the normal production in the barn?

G All-in, all-out (batch system)
Note: this may apply to individual rooms

G Continuous system

4. Normal range of pig weights in barn: Weight In = __________ lb

Weight Out = __________ lb

5. Overall Dimensions of barn (in feet) - Length = __________

Width = ___________

Ceiling height = ___________

6. Ventilation system: G fan powered

G natural ventilation

7. Barn layout: G one room

G more than one room

8. Sketch of barn layout (showing numbered rooms, if more than one), and/or written description of building, with dimensions:

9. Water system - describe (number of waterers per pen, in feeder, on wall, etc.)

10. Is water meter data available for this barn?

- G Yes - details ______________________________
- G No

11. Type of feed:

- G Dry feed
- G High Moisture corn
- G Other - details ________________________

Attach details of the most common feed formulations (i.e. relative amounts of corn, grain, soybean meal, pre-mix, etc.). Attach feed tags for premix used.

12. Feed system?

- G liquid feeding
- G wet/dry feeders
- G floor feeding
- G dry feeders

Make of feeders, age of feeders, etc. ______________________________

____

13. Manure system

G all storage under barn

G partial storage under barn plus outside storage

G no storage under barn (removed frequently)

14. Description and dimensions of all storages, including gutters

15. Describe the system of manure transfer to storage. Include details on how often gutters are emptied (i.e. when pigs leave room, when gutters full, etc.) plus details on transfer system.

16. Are outside storages covered to exclude precipitation?

G Yes

G No

G Does not apply

17. Are manure additives used?

G Yes - details ____

G No

Information Gathered (what date?):
Information gathered by whom?:

form name: Farm General Info
date: 98.02.24

Farm Data Sheet

Swine Manure Production Study 1998-99

Ron Fleming (519-674-1612), Malcolm MacAlpine (519-674-1602),
Ridgetown College/University of Guelph

Name of Farmer: ____

Date of start of study: ______________________________

To accurately predict manure production volumes, we need details on all inputs and outputs. There are 4 major areas: Water, Pigs, Feed, and Manure.

A - Water - Record water meter reading at the start of the study and near the start of each month.

Date	**Water Meter Reading**

B - Pigs - Record weights and numbers of all pigs in and out.

Number of pigs in barn at start of study ______________________

Date	Number of Pigs Brought In	Number of pigs shipped out	Total weight (or average weight)

C - Feed - Record all feed inputs - specify units of measure (e.g. kg, tonne, etc.)

Feed Number System

Feed Number 1 refers to: ____

Feed Number 2 refers to: ____

Feed Number 3 refers to: ____

Amount on hand at start of study ______________________________

Date	**Feed Number**	**Amount brought in**

D - Manure - Record level of manure in long-term manure storage(s) monthly, as well as the manure removed from storage. Note: If spreading manure, record the amount in the storage just before spreading starts and just after spreading finishes. Also, estimate the total volume of manure spread and record it separately. Any information about in-barn short-term storages may be recorded separately.

Storage Number System

Storage Number 1 refers to: ____

Storage Number 2 refers to: ____

Storage Number 3 refers to: ____

Storage Number 4 refers to: ____

Storage Number 5 refers to: ____

Date	Storage Number	Distance from top of storage to liquid level

form name: Farm Data Sheet
date: 98.02.26