

Evaluation of a 1000-head “Environmentally Friendly Facility” Swine Finishing Barn

Final Report



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INTRODUCTION

This is the final report of the Ridgetown College - University of Guelph research project: **Evaluation of a 1000-head “Environmentally Friendly Facility” Swine Finishing Barn**, funded by Ontario Pork and coordinated by Frank Hogervorst, Avonbank Farm Equipment Ltd., Granton, Ontario. The barn is located on a swine farm near Exeter, Ontario. This report outlines the results of studying this novel concept in barn construction over a one-year period

Liquid manure systems are used on most swine farm operations in Ontario, especially in the new barns. Typically, animals are housed on fully or partially slatted floors. Feces, urine, spilled water and feed, washwater all fall through the slats and are stored as a liquid. This system is very labour-efficient and eliminates the need to supply large amounts of bedding material. However, the handling, storage and land-application of liquid swine manure have raised environmental concerns. They are regarded as having higher levels of odours than “solid” manure systems, due to the anaerobic conditions and the nature of the gases and compounds given off during storage and spreading. Also, the potential to contaminate surface water or groundwater is higher than with solid manure systems, because the manure is in a “flowable” form.

BACKGROUND

In the past few years, several High-Rise™ swine barns have been built in Ohio, USA. The High-Rise™ barn is a two-storey hog barn where the pigs are raised on a slatted floor in the top storey. Manure falls through the slats to land on a bed of wood fibre (or other material with high carbon content). Air is used to dry the manure so that it can be removed as “solid” manure after a period of up to a full year. All room ventilation air is drawn down through the slats to exhaust through wall fans in the lower floor. In addition, aeration air is forced up through the carbon material/manure. This air is blown through pipes buried in the floor and upwards into the material via holes drilled through the concrete into the aeration pipes.

In 2000, Frank Hogervorst, Avonbank Farm Equipment Ltd., organized a tour to visit one of these barns to assess the potential for application to Ontario building design. The visit showed that the technology could be adapted for southwestern Ontario farms.

Based on the observations in the US, and on comments and ideas from a number of people, a variation of the Ohio designs was built on an Ontario farm. Frank Hogervorst, coordinator of this effort named the new version the **Environmentally Friendly Facility** (EFF). This concept was incorporated into a new hog barn constructed during the summer of 2000, near Exeter, Ontario.

OBJECTIVES

This study set out to follow the progress of this new barn during its first year of operation. The objectives of this project are:

- 1) to assess the viability of this technology as a way to handle liquid hog manure - including: volumes of manure produced, nutrient concentrations, and economic considerations;
- 2) to determine the impact of this type of housing and manure system on the odours and ammonia exhausted from the barn as well as the environment inside the barn;
- 3) to determine the impact of this housing system on the production of hogs;

EXPERIMENTAL PROCEDURE

The Barn - The barn was constructed in the summer of 2000 on a farm near Exeter, Ontario. Figures 1 and 2 show the barn during construction - Figure 1 showing the lower floor, and Figure 2 showing the upper floor before the barn walls were built. The barn is a fully slatted, fan-ventilated, hog finishing barn. The barn is 51.2 m by 16.76 m (168 ft by 55 ft) with ceiling heights of 2.4 m (8 ft) upstairs and 2.7 m (9 ft) downstairs. The total volume of the lower floor (manure storage) is 2,355 cubic metres (83,160 cubic feet). This depth of manure storage, if used for liquid manure, would be enough to handle the production for just over one full year (about 2,093,000 L), based on 1000 feeder pigs. (estimated using NMAN - OMAFRA, 2000)

Upstairs, there is a center alley with 34 pens in one open room. There are 32 pens at 3 m x 7.9 m (10 ft by 26 ft) and 2 pens at 2.4 m by 7.9 m (8 ft by 26 ft). The barn is run as a continuous system - pigs are moved into the barn at regular intervals and they are shipped out when ready.

The feeding system consists of BSM wet/dry feeders with three water nipples per feeder. No additional water nipples were installed in the pens. The feed contains corn, soybean meal, shorts, premix, fat and a binding agent. Feed is delivered to the farm in bulk and delivered to the feeders with an auger system.

The barn ventilation was set up in three stages, controlled by thermostats. The first



Figure 1 Downstairs in barn, during construction, showing concrete columns supporting slatted floors. Ventilation exhaust fans were installed in wall openings.

level was set to operate constantly, the second level was set to operate intermittently in colder months and the highest level would start in the warmer months. Fresh air entered the barn through the eave vents, then entered the room through ceiling-mounted actuator-controlled inlets. These inlets were spaced along the length of the barn in two rows, roughly in the middle of the pen length of each row of pens. After circulating in the room and slowing down, the air dropped through the floor and exhausted through the exhaust fans in the walls of the lower floor. In total, there were 16 fans - four at 460 mm diameter, 8 at 640 mm, and 4 at 910 mm (18, 25 and 36 inch diameter). The barn was oriented in more-or less a north-south



Figure 2 Slatted floor (concrete), nearly complete

direction. The exhaust fans were set up to blow air from both sidewalls and each quarter of the barn was set up identically. The fans all had shrouding to direct the exhaust air, with the fans for the first level of ventilation having hoods that deflected the exhaust air downwards.

The aeration system in the lower floor consisted of a series of pipes running from the center to the ends of the barn. In the center was a plenum that was 810 mm wide by 910 mm deep. It was covered with concrete slabs, at floor level. The pipes running out from this plenum were 100 mm diameter and were spaced at 600 mm apart. These were buried in the concrete floor, 25 mm below the floor level. A 9.5 mm (3/8 inch) hole was drilled downward into the pipe after the concrete floor had hardened. These holes were spaced at 300 mm along the entire length of the pipes. At the side of the building, in the center, was the fan location for the aeration system. A small chamber was built on the outside of the barn. In it were mounted two inline centrifugal fans of 460 mm and 2.2 kW (18 inch, 3 hp). These blew air into the plenum. They were set up so that air from inside the bottom floor area could be circulated through the system, or fresh outside air, or a combination. These fans ran constantly.

A submersible pump was installed in the aeration plenum, just below the aeration fans. This was to handle any liquid manure that might find its way into the aeration system (after soaking through the bed of straw). Initially this was set up to pump any liquid that might accumulate into a nearby liquid manure storage (serving another barn).

Startup - The manure floor was loaded with 251 big round straw bales weighing about 200 kg each, giving a total mass of 50,200 kg of straw. The straw was placed in the manure storage using a skid steer loader. The wrap was cut off the bales, then the bales were either rolled out by hand or shaken out using the loader. The final depth of straw throughout the bottom floor was about 1.8 metres (6 ft). The first pigs entered the barn in early September. The barn was gradually filled with pigs as weaner production allowed, and was full by November 7, 2000. Staff from Ridgetown College visited the site during construction in July and again in late August, then at regular intervals during monitoring.

Pigs are brought into the barn weighing 32 kg (70 lb) and shipped at 109 kg (240 lb). Pigs are in the barn for approximately 90 to 100 days. Pens are washed down using a pressure washer between lots. A water meter was installed on the main water line to monitor total water use for the barn.

Monitoring - Monitoring was set up and initiated on November 1, 2001. Two Spectrum Technologies micro-computers with temperature sensors and thermocouples were placed in the straw in the ground floor. Another Spectrum Technologies temperature/relative humidity sensor was placed in the upper floor, midway along the center alley of the barn. The water meter reading was recorded. Pictures were taken of the manure storage area to help document changes over the year. Monitoring locations for ammonia levels were determined. Ammonia levels were measured using a Gastec sampler and ammonia sample tubes for the expected concentration range (shown in Figure 3). Straw samples were also collected.

The site was visited monthly to collect samples, take ammonia readings, read the water meter, download temperature data from the microcomputers and monitor how the barn was working. The farmer started a log, recording the numbers and weights of pigs entering and leaving the barn, as well as dates. Also, a log was started of feed inputs to the barn. A hog inventory was recorded monthly, as a check on pig numbers. In addition, the farmer recorded the amount of time that the liquid manure sump pump ran, in order to establish the volume of liquid that leaked through the bed of straw.

Odour ratings were taken by a panel on July 24, 2001 and August 3, 2001.

Measurements were taken using a Scentometer, which is held up to the nose of the odour panelist. Air is drawn through a carbon filter and through precision holes that allow outside unfiltered air into the chamber giving different levels of dilution, depending on which hole is opened.



Figure 3 Malcolm MacAlpine taking a reading of the ammonia level at exhaust fan

RESULTS AND DISCUSSION

Ventilation System - With the heavy snow in the winter of 2000/2001, and with the fans mounted on the manure storage walls close to ground level (see Figure 3), some of the Stage Two fans had snow blow into them. This melted and froze, thus preventing the fans from turning. The shafts then broke when the fans started. These fans were repaired in March when it was finally discovered they were not functioning. The shrouding impaired viewing the operation of the fan blades. Even though the fan motors would start and operate as normal, the fan blades were not turning.

Ammonia Levels - Measurements of ammonia (as shown in Figure 3) were made monthly at eight locations - three outside of the barn and five inside the upper floor. The outside locations were: at the continuously running exhaust fan in the southeast part of the barn (designated as FS); at the exhaust fan in the northeast part of the barn (FN); just inside the manure storage door (Man). Inside locations were (all in the upper floor): next to the heater near the north end of the barn (NH); north end between heater and wall (NW); middle of barn (M); next to the heater near the south end of the barn (SH); south end between heater and wall (SW).

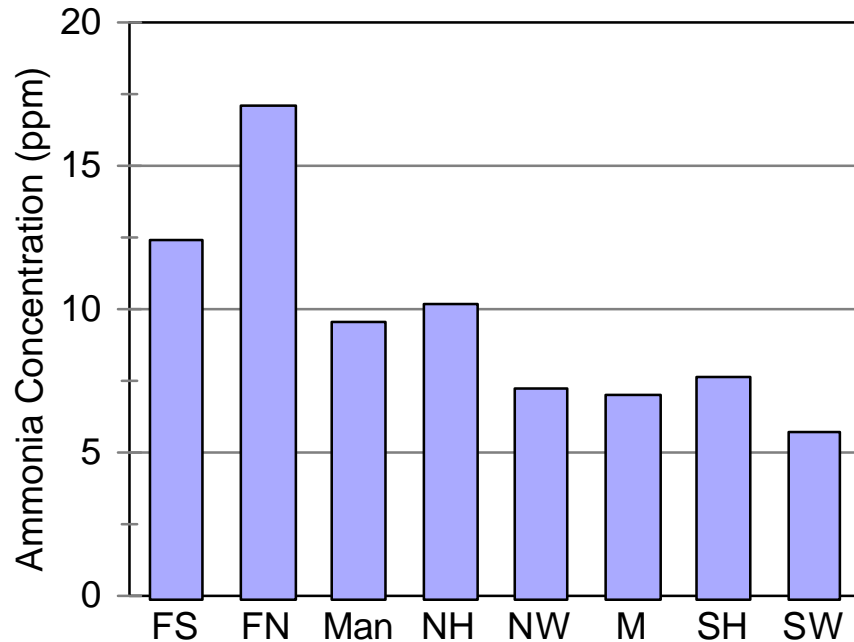


Figure 4 Average ammonia concentrations at different locations:

- FS** - Fan on South end of barn - outside
- FN** - Fan on North end of barn - outside
- Man** - Measured just inside manure storage door
- NH** - Next to heater on North end of barn - inside pig area
- NW** - between heater and wall - North end - inside pig area
- M** - Middle of barn - inside pig area
- SH** - Next to heater on South end of barn - inside pig area
- SW** - between heater and wall - South end - inside pig area

The averages of the monthly readings are shown in Figure 4. Ammonia levels measured in the manure area were an average of 10 ppm. Ammonia levels were higher in the air leaving the North-East exhaust fan (avg 17 ppm) than the South-East fan (avg 12 ppm). Inside the barn, ammonia levels were higher in the North end (avg of 10 ppm) than the South end (avg of 7 ppm). The north half of the barn had mesh pen fronts and the south half of the barn had solid pen fronts

(see Figure 5). Ammonia levels in the barn were much lower after March, 2001. The main reason for the high readings during the first several months is believed to be due to problems with the exhaust fans. The second stage ventilation fans froze and the shafts broke at some point during the winter, resulting in less air exhaust than was required. The fans were repaired in late March. Further evidence of ventilation system problems may be found by examining the relative humidity data for the room - during November and December, the relative humidity was higher than 80% most of the time (the temperature stayed very close to 21° C during this period). For a grower-finisher barn such as this, it should be possible to keep the RH at 75% or lower, even without supplemental heat (Huffman, 2001). This helps confirm that the exhaust rate was lower than it should have been, which would have contributed to higher barn ammonia levels. Even considering this ventilation problem, the ammonia levels were no higher than typical slatted floor barns with liquid manure under the slats. These values would be in the range of 15 to 30 ppm, with occasional values of over 40 ppm - and 5 to 10 ppm in the summer (Huffman, 2001).



Figure 5 Open vs solid pen fronts

The warmer weather with higher ventilation rates helped lower the ammonia readings in this barn to less than 5 ppm from May until clean out. Variations in ammonia readings over time are shown in Figure 6.

Odour Ratings - An odour panel of four people was used to assess odours. As was mentioned earlier, a Scentometer was used. Background odour levels were measured at a number of similar swine operations where conventional liquid manure systems were used. To standardize the comparisons, we have typically taken readings at a distance of 30 m downwind of the source of odour (e.g. fan, manure tank, etc.). Normally, the closer to the source of odour, the greater the odour level. In this case, however, odours were not detected at the typical 30 metres distance from the barn. Measurements were taken downwind from the fans at 10 metres so that some odour could be detected. The units used are “dilutions to threshold”, and they represent the ratio of clean air to odorous air that would be needed before the odour could just barely be detected. The higher the number, the greater the odour.

Typical values for hog barns with liquid manure (at a distance of 30 m) have been in the range of 3.0 to 18.0 dilutions to threshold, with an average of 11. For the barn in this study, the odour was too faint to measure at 30 m so was measured at 10 m from the fan. On one occasion, the geometric mean of the odour panelist scores was 3.7 and on another occasion it was 24.3 (note that on this occasion, the odours were too faint to register at 30 m). Unfortunately, we do

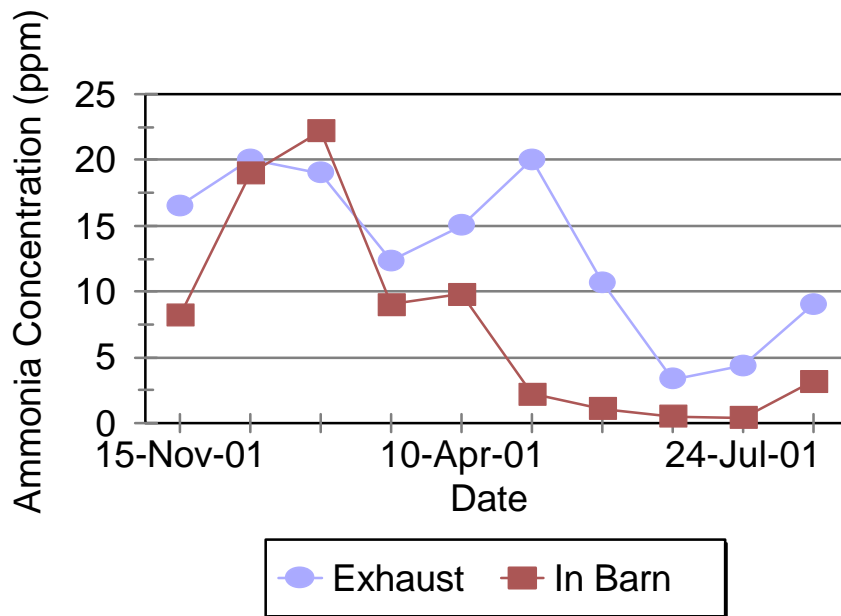


Figure 6 Average ammonia readings inside the barn and in the exhaust air, during the study period (inside - 5 locations, exhaust - 3 locations)

not have a good database of odour values for conventional barns at the 10 m distance, but one would expect these values to be considerably higher than the 30 m values.

In addition to odour intensity, the odour character is important. Two odours may be equally strong, but one may be much more offensive than the other. There was only a slight odour of “liquid hog manure” at this barn and the odour seemed closer to what might be encountered with spoiling feed or silage.

Generally, the odour level seemed to be less than for conventional barns and the odour character was less offensive. Presumably this is at least partly due to the reduced presence of anaerobic bacteria (bacteria which break down the manure organic matter in the absence of oxygen - typical of liquid storage systems).

When the barn was cleaned out and the dry manure spread on the land, there was a significant odour, but, again, it was not typical of liquid manure. It more closely resembled that of a solid hog manure system. While this odour was offensive, it was not as bad as normal liquid hog manure being spread. Also, the odour seemed to disappear rather quickly as the manure dried out.

Water Use - Water readings were taken from October 14, 2000 to September 1, 2001. Daily water consumption for that time period ranged from 3,029 litres to 5,193 litres with an average of 4,610 litres. The average water use per pig per day was 5.0 litres. In a recent comparison of

feeders in hog barns, Fleming et al. (1999) measured an average water consumption of 5.5 litres per pig per day for conventional barns using wet/dry feeders, and 7.9 litres per pig per day for conventional barns using dry feeders. The relatively low water use in the study barn suggests the barn is successfully set up to reduce wasted water. This is accomplished in part by the use of wet dry feeders (that tend to reduce the amount needed). Total water used over the period specified was 1,481,000 litres (325,780 gallons). The monthly variation in water use is shown in Figure 7.

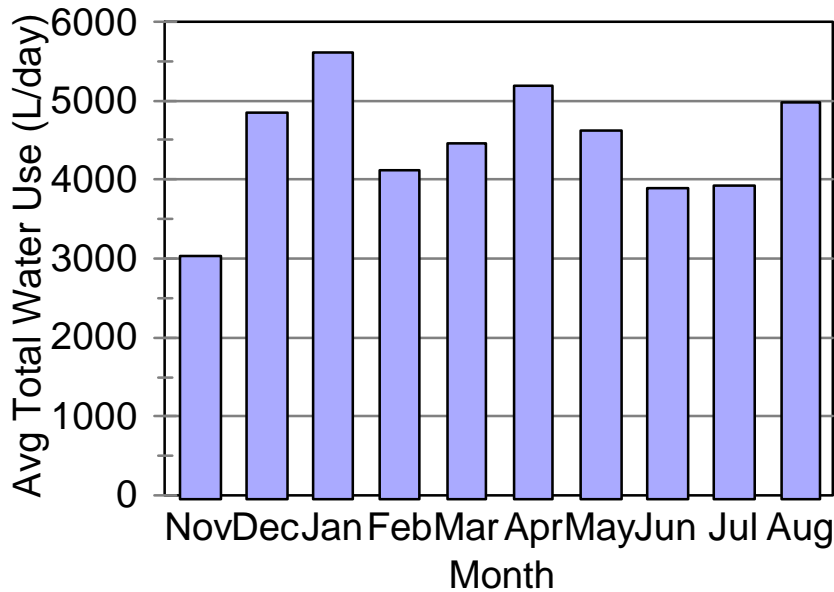


Figure 7 Total water use per day, averaged by month, over the study period

Manure and Straw Characteristics - Initially, manure in the lower floor was all absorbed by the straw or dehydrated with the aeration. Manure formed a crust on the straw surface and did not appear to be soaking downward into the straw. Very little settling of the straw was noticed prior to the March, 2001 visit. At this time, some puddling of manure on top of the straw was observed where manuring was heaviest. The depth of straw had shrunk by about 33% overall. The straw depth at clean out was about 50% of the original depth.

Temperatures in the straw/manure remained about the same as those in the air space in the manure storage (around 10 to 25 degrees C.) This was measured using Spectrum Technologies data loggers that measured the temperatures using a thermocouple and also measured air temperature. There was little or no heating of the manure. There was no evidence

that any composting took place in the straw/manure mix. It is unlikely good composting could be attained in this environment since it would be difficult to achieve the ideal moisture and C:N ratio to allow the straw and manure to compost.

The pigs did not manure uniformly over the floor area, thus some areas in the bottom floor were still quite dry while other areas were getting wet. Manuring may be influenced by the layout of the penning in the barn. The north half of the barn has mesh pen fronts, allowing hogs to socialize across the center alleyway. The south half has solid pen fronts.

The pigs appeared to manure the most along the center alley. As the year progressed the center straw became laden and eventually overloaded with manure. At this point, it appeared that manure was able to move laterally - it fell on top of the manure crust and could move sideways short distances on top of the crust. A small amount ended up near the access door by early April. Small square bales of straw were placed at the door to stop this movement and capture the small amount that might otherwise have escaped when the door was opened. Generally, the straw along the walls of the barn (and several other areas) remained dry throughout the year with little manure falling onto it. At clean-out it became necessary to mix the dry straw with the semi-liquid straw/manure to remove it from the manure area.

During the year, a quantity of liquid manure leached through to the aeration plenum and accumulated there. This liquid was pumped out on seven occasions from December to March. The total volume pumped was 12,725 litres (2,800 gallons). From March until mid-May the plenum was pumped out twice weekly with a total volume of approximately 36,300 litres (8,000 gallons). From mid May until clean-out approximately another 25,500 litres (5,600 gallons) were pumped. The total volume of leachate pumped was approximately 74,500 litres (16,400 gallons). Based on typical manure production estimates for the sizes of pigs involved in the study, this represents approximately 3.7% of the total manure produced. The leachate was, of course, filtered by the straw. The dry matter level was only 1.4%, compared to an estimated dry matter of about 6% for the raw manure.

The total volume of manure and straw removed from the storage after almost one year was 832 cubic metres (29,383 cubic feet). This manure/straw mixture filled 35% of the total storage depth.

Pests - The dry straw in the manure storage and the small amount of feed dropping into it provided a desirable environment for mice and rats. They were able to burrow into the dry areas. Rodent populations became high enough that it was necessary to bait the manure storage to get them under control. Rodents were still present at clean out although not in as large numbers as observed earlier.

Rodents can be a problem in any pig barn. In some barns they can cause significant damage to building insulation and wooden structural elements. Due to the concrete sandwich wall construction in this barn, that was not the concern. Rodents also harbour disease, so it is essential to keep them under control. With the large amounts of straw in this type of barn it gives an ideal environment for the rodents, and thus requires a higher level of management to keep them under control.

This type of manure system is also more prone to fly problems - conditions exist which allow flies to go through their breeding cycle. In a typical liquid storage, there is no dry area in the

manure storage for this to occur. The manure area was sprayed with a residual pesticide to keep populations in check..

Manure storage clean out - The lower floor was cleaned out from August 21 to 24, 2001, moving a total volume of 832 cubic meters (29,383 cubic feet) of dry manure. This manure filled approximately 35% of the total storage capacity and required 103 manure spreader loads to empty. It is estimated, using NMAN software that the hogs would have produced 1,971 cubic meters (433,570 gallons) of liquid hog manure. Therefore, the total volume of manure was reduced to about 42% of what it would have been in a liquid manure system. In a liquid system, using a common liquid manure spreader with a capacity of 11.4 cubic meters (3000 US gallons), would have required 145 loads to spread the manure. The farm owners felt that it was significantly easier to handle the dry manure than it would have been to handle liquid manure - they have liquid manure in other parts of their operation.

Two dry manure spreaders were used. Each had a capacity of 14.5 cubic meters (400 bushels) and each was equipped with hydraulic end gates to prevent any sloppy manure from flowing out during transportation. The manure was moved out of the manure storage using a skid steer loader (see Figures 8 and 9) which had to drive out the centrally-located access doorway to the spreaders parked just outside the manure storage. The clearance was not great enough that the manure spreaders could be parked inside the manure storage for loading.



Figure 8 Skid steer loader moving below the slatted floor during unloading

The skid steer could easily be operated in the spacious manure storage with only two rows of columns to negotiate. The operation required three operators - one on the skid steer, and one driver for each spreader. The manure was spread approximately two km away on a harvested wheat field. The speed of emptying the storage was limited by the size of equipment used and the distance to draw the manure.

It was necessary to mix the dry straw with the wetter areas to soak up the semi liquid portion of the manure. This involved moving the straw to areas that had semi liquid manure using the skid steer loader, which added to the time required to clean out the barn. The dry straw was primarily located around the outside edges of the manure storage. In the parts of the USA where this type of barn is used, it is common to move the manure from one zone in the barn to another, a few times during the year. This helps to mix these wetter and dryer areas more thoroughly, though it takes more labour.

It was initially expected that some composting would take place and the material removed would resemble composted manure. This was not the case, as has been mentioned earlier.

During clean out it is possible to work in the manure storage and operate equipment without worrying about the presence of dangerous gases. These gases are produced under anaerobic conditions, whereas this storage was well-aerated and

stayed aerobic throughout the year. Odours resembled those of a dry hog manure pack without the ammonia and sulfur-related odours present in liquid hog manure. The only gear required for the skid steer operator was a rain suit, since the barn was still full of hogs. However, with the activity in the manure storage, pigs did not appear to defecate to any extent.

With this system, the timing of cleaning out the manure storage is less critical than with liquid manure. The manure storage does not become full as can happen with liquid storages. Rather, timing is based on the point at which the farmer decides he can move the manure, has a place to put it, or the straw is becoming laden with manure. If the manure can't be moved and the straw is becoming saturated with manure, straw could be added to the manure storage to help extend the storage time. This provides considerably more flexibility than is found with liquid systems.

Manure Nutrients and Metals - Manure samples were collected as the solid manure was being unloaded from the barn. No samples were collected prior to this, except samples of the liquid manure that leaked through the straw bed and was pumped to the liquid manure storage. Nutrient analysis results for the solid manure and leachate samples are shown in Table 1.

Average nutrient levels, on a "Dry Matter" basis, in the solid manure were:

Nitrogen	3.95%	(Standard Deviation 1.45),
Phosphorous	2.05%	(SD 1.18),
Potassium	2.56%	(SD 0.99),
pH	8.2	(SD 0.6) ,
Ash	18.8%	(SD 6.59).



Figure 9 Loading solid manure spreader

Table 1 - Average nutrient content of manure from the Environmentally Friendly Facility, compared to selected other materials.

Material	% N Dry Weight	% P Dry Weight	% K Dry Weight	% Dry Matter Wet Weight	% Ash Dry Weight	pH	% C Dry Weight	C:N ratio by weight	# of samples
EFF barn dry manure	3.95	2.05	2.56	38.6	18.8	8.2	40.5	13.95	36
EFF barn leachate	9.7	1.39	22.9	1.4	61	8	24.7	2.6	2
straw - at start	0.5	0.04	0.9	95.9	33.4	7.6	46.2	92.3	1
<i><u>Selected values - for comparison*</u></i>									
straw	0.49	0.08	1.4	90.4	6.04	7.51	43.9	96.1	12
liquid hog manure	17.3	3.44	11.8	2.73	38.6	7.64	36.2	2.27	6
compost made with straw and liquid manure	3.2	1.59	4.3	40.9	31.8	8.1	33.8	10.7	19
slab wood	0.3	0.03	0.17	67.4	5.45	6.55	48.3	177	2
tree leaves	1.15	0.12	0.83	47.4	17.8	6.4	46.7	40.2	8
corn stalks	0.6	0.11	0.6	72.5	11.3	7	43.4	71.5	1

* selected values from a study on composting (Fleming and MacAlpine, 2001)

The average dry matter content of the manure was 38.6% (SD 23.05). Reporting of the concentrations on a “Dry Matter” basis allows for easier comparison of nutrients contents of materials having different moisture contents. Many people are, however, more familiar with concentrations on an “As Is” basis.

On an “As Is” basis, nutrient levels were as follows:

Nitrogen 1.4% (SD 0.94),
Phosphorous 0.67% (SD 0.49),
Potassium 0.85% (SD 0.44).

Typical liquid manure would have nutrient values (As Is basis) as follows:

Nitrogen 0.39%
Phosphorous 0.12%
Potassium 0.17%

These values are based on the average of 190 manure analysis results for liquid swine manure between 2 and 6% dry matter (OMAFRA 2000). Using these average numbers, the approximate total nutrients in the manure would be in the order of 7700 kg N, 2400 kg P, and 3400 kg K. The “actual” calculated nutrients, when spread on the fields were in the order of 6800 kg Nitrogen, 3250 kg Phosphorous, 4140 kg Potassium (note that these are totals for N, P, K and not “available” amounts at time of spreading, nor are the P and K in the form of phosphate or potash). It is impossible to draw conclusions with any certainty using these predictions for liquid manure. It does however appear that the conversion to solid manure has not led to significant losses of N. One would expect that P and K are actually increased in this system, through the

addition of straw.

The manure system represents a process which concentrates nutrients by evaporating water, as can be seen from the nutrient concentrations. Care must be taken in the calculation of spreading rates based on crop nutrient needs, in order to avoid over-applying nutrients.

Heavy metal concentrations were measured in several samples. The results are shown in Table 2. Arsenic, Cadmium, Cobalt, Mercury and Lead were not detected in the manure sampled.

Other levels are in line with levels in either liquid swine manure or composted swine manure from the study noted. There are no standards for metals in liquid manure currently. This would only be an issue if a farmer wanted to compost this manure and sell it as compost. Certain standards would then apply, and it is for this reason the values are given.

Table 2 Average concentrations (Dry Matter Basis) of heavy metals in EFF solid manure, compared to liquid manure and finished compost

Trace Elements	Lower Detection Limit * (mg/kg)	EFF Barn Swine Manure (mg/kg)	Liquid Swine Manure ** (mg/kg)	Straw Compost >70 days ** (mg/kg)
Arsenic (As)	1	0.5	1.45	0.9
Cadmium (Cd)	0.5	0.25	0.43	0.3
Cobalt (Co)	2.5	0.48	2.7	1.1
Chromium (Cr)	5	2.38	4.4	5.2
Copper (Cu)	5	399	172	35.9
Mercury (Hg)	0.01	0.005	0.01	0.02
Molybdenum (Mo)	2.5 or 1.0	2.63	7.95	4.2
Nickel (Ni)	5	5.67	8.7	3.2
Lead (Pb)	5	2.5	6.5	10.1
Selenium (Se)	0.01	1.34	2.1	0.7
Zinc (Zn)	25	835.5	758	224
Number of Samples		6	2	10

* In cases where the concentration was less than the lower detection limit, a value representing one half the lower detection limit was used to calculate the average values (this was a frequent occurrence)

** from Fleming and MacAlpine, 2001

Hog Production - The barn owners in this project felt the pigs performed well in this barn. Hogs reached finished weight in about 90 to 100 days, which was better than their conventional barns. They felt the air quality, once the ventilation was repaired in March, was excellent - as demonstrated by reduced ammonia readings and odour ratings done on site. They also had positive comments on air quality and odours from the herdsmen and from visitors to the barn.



Figure 10 Feeder pigs in group pens with slatted floor

Table 3 contains a summary of various pig performance criteria for this barn, and includes a comparison to a number of barns that were part of a separate study performed earlier. The numbers are pretty well in line with what was measured in other barns - there is no evidence that pig performance was affected by the barn system. Death loss in this barn was 3.86 %, slightly higher than an estimated average of 3.0% (Smith, 2001). This could, at least in part, be due to health problems caused from the poorly operating ventilation system during the first several months.

Table 3 The production of the “Environmentally Friendly Facility” compared to conventional barns using different feeding systems (from Fleming et al, 1999)

	Environmentally Friendly Facility	Wet/Dry Feeders	Liquid Feeders	Dry Feeders
Barn Capacity (pigs)	1000	1262	1800	865
Feed Conversion (kg feed / kg gain)	2.7	2.7	2.7	2.4
Water used Litres/pig/day	5	5.54	7.4	7.93
Area square metres per pig space	0.86	0.87	1	0.95
Litres water / kg of weight gain	5.41	7.01	7.53	9.86
Average Daily Gain kg/pig/day	0.65	0.72	0.99	0.64
Number of sites measured	1	12	1	4

Barn Performance - As with any new operation, there were some problems that occurred after startup. There were respiratory health problems with the pigs - likely due to poor ventilation through the winter months, caused by fan failures, mentioned earlier. There was also a problem with the feed, up to late November, that caused scouring and poor growth. This was corrected in December. The manure storage aeration fans were prone to failure, likely due to the way they were mounted. Initially, the inline centrifugal fans were mounted blowing downwards instead of the conventional horizontal mounting) into the plenum. During the cold months, they drew air out of the manure storage and blew it into the plenum so that warm air was always used for aeration of the manure. In May, the fans were moved to the outside of the manure storage plenum and they were oriented horizontally. This appeared to end the problems experienced earlier.

At clean out, it was obvious that the aeration system could not keep up with the liquid deposition in certain areas. Ideally, all the manure would be dried out, but this was not the case. The farmers felt that this could be managed by increasing the depth of straw in the manure storage area in those parts of the barn where the greatest amount of manure falls. The pigs seemed to manure in concentrated areas in the pens with open mesh partitions, thus not efficiently using the straw in the manure storage below. The pens with solid partitions did not have as pronounced an effect on manuring habits. The owners are planning to use solid partitions on all pens to take advantage of these observed manuring habits. Manuring in all pens seemed to be concentrated to the central portion of the barn, along the alley. When the manure

storage was filled with straw in 2001 (i.e. after clean out), the straw was piled as high as possible in areas that had more manure previously, in order to handle the larger manure volumes.

The process of cleaning the manure storage out plugged a number of holes in the aeration system. A pressure washer and a pointed instrument were used to clean out each hole.

The liquids that leached through the straw into the plenum were pumped out into a liquid manure tank next to the barn. Some areas of the manure storage had straw that was still dry at clean out. To utilize all of the manure and straw, the owners plan to pump the liquids through a perforated pipe suspended above the previously dry areas, expecting the straw will absorb the liquids. This would prevent the need to have a liquid manure storage to hold the small percentage of manure that leaches through the straw.

Summary

1. This system of handling hog manure has shown to be a viable alternative to liquid manure. The use of straw and forced aeration to transform the liquid hog manure into a dry manure was quite successful. This system greatly reduced the volume of manure produced, thus concentrating the nutrients and making it more easily transported. Even after the addition of the straw, there was a 58% reduction in manure volume compared to liquid hog manure. The manure did not appear to compost, but simply dried down to a final moisture content of 61%.
2. The economics of this system has yet to be evaluated. The added costs are:
 - a) construction with the installation of the aeration system and the manure storage door.
 - b) the installation and operation of the aeration fans.
 - c) the installation and operation of a sump pump to drain the aeration plenum
 - d) the cost of the straw and labour to spread it out in the manure storage
 - e) the cost of equipment to handle dry manure if not already in use on the farm and the labour to operate it

The cost savings:

- a) liquid manure handling equipment, spreaders and pumps and the labour to operate them
- b) possible improved herd health and improved pig performance due to a better environment in the barn
- c) the reduction of manure volume, thus reducing transportation costs.
- d) the ability to process the manure further through composting to eliminate odours, pathogens, destroy weed seeds, to greatly reduce volumes of manure, and increase its market value.
- e) the improved environment in the barn should reduce veterinarian costs as well as an improved working environment for the herd workers in the barn.

3. This system has caused a significant reduction in odours exhausted from the barn, as well as those inside the barn. Ammonia levels, once the ventilation system was repaired, were very low. (Ammonia readings in the barn for winter months should be re-measured now that the ventilation system is operating properly, to verify that the ventilation system problems caused higher ammonia readings than should be expected). Odours measured outside the barn were very low and less offensive than liquid hog manure. Odours during manure application to the field were less offensive than liquid hog manure.
4. Less than 4% of the total initial liquid manure drained through the system and had to be handled. A system was eventually set up to pump this onto dry areas in the straw bed. This, therefore eliminates the need to spread any manure as liquid, which eliminates the risk of macropore flow of liquid manure to tile drains - a potential impact that farmers with liquid systems must take extra steps to guard against.
5. The owners feel there was an improvement in hog production using this system with days to market at around 90 to 100 days. Feed conversion and average daily gain were similar to conventional barns. Water use was significantly lower than conventional barns.
6. The system creates much more flexibility in determining manure spreading times than typical liquid systems.

Recommendations for Future Research

1. Further monitoring of this barn following the changes made for this year could be valuable. Monitoring of air quality in the barn and its impact on herd health and performance could be done in comparison to a conventional barn.
2. Treatment of the manure once removed, by composting, could help address the issues of odours, pathogens, impacts on water quality and nutrient management.
3. Monitoring other barns that have been developed using this barn's technology could give a greater data base to help determine the impact of management, livestock genetics, and other factors on performance.

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