VAN KEMPEN RECEIVES SWINE INDUSTRY AWARD FOR INNOVATION

Congratulations to Dr. Theo van Kempen, who recently received the National Pork Board’s Swine Industry Award for Innovation for a project to recycle swine waste. The presentation was made at the meeting of the American Society of Animal Science’s Southern Section in Mobile, AL. One abstract is selected each year for this award, which promotes and rewards original and innovative ideas that are scientifically based and relevant to the pork industry. Read Dr. Van Kempen’s winning abstract below.

His report on the RE-Cycle project begins on page 2.

RE-Cycle:
Recipe for waste-free swine production.
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A novel swine production system was developed that has the potential to be profitable while substantially reducing waste. At the basis is a modified housing design. Instead of urine and feces mixing in a pit, they are collected separately, using an inclined conveyor belt placed in the pit.

With the belt sloped 4 percent, urine (1.5 ± 0.4 liter per pig per day, data for 80 grower pigs) runs off the belt into a collection gutter, which takes it out of the building into a closed storage container. Subsequently, ammonia is extracted by chemisorption using a zinc-sulfate column. Efficiency of ammonia extraction was 99.7 percent when the column first went into use, decreasing to 90 percent as the column became saturated, at which time the column was regenerated and ammonia was recovered. The ammonia was then processed into ammonium sulfate fertilizer.

Feces are passively dried on the belt. This material was harvested at 6 a.m. each day at 54 ± 9 percent dry matter. On a dry matter basis, 17 ± 2 percent of feed consumed was harvested as feces. Cross-contamination of the urine and feces was estimated at less than 1 percent, based on mineral profiles. As a result of separating urine and feces, ammonia emission was 1.0 ± 0.2 kilogram per pig place per year.

Dried feces can be converted to green energy using a steam-reforming gasifier. Feasibility tests carried out in conjunction with MTCI (MD) and EPI (ID) showed that fecal material performed well as a gasifier feedstock. Tests with a gasifier built by BK Technologies (CO) yielded a product gas with 28 percent H₂, 25 percent CO₂, 23 percent alkanes, 11 percent N₂, and 12 percent CO₂. This product gas can be used for the production of electricity or for chemical synthesis of diesel or ethanol.

Ash derived from gasification contains approximately 11.5 percent Ca and 13 percent P. The solubility of these minerals at pH 2 was 79 ± 0.2 and 85 ± 0.6 percent, respectively. Digestibility for P in vivo was 88 ± 2.7 percent of that of dicalcium phosphate. Thus, this ash may be used as a feed ingredient in pig diets.

In summary, the RE-Cycle system addresses environmental concerns that face the swine industry while supplying green, or renewable, energy.

Key Words: Swine, Manure, Belt

ALUMNI REUNION OF NCSU ANIMAL SCIENCE CLUB SLATED

The Animal Science Club (formerly the Animal Industry Club) at North Carolina State University will host an alumni reunion in conjunction with the Club Day Livestock Show April 4-5 at the new Beef Educational Unit, located off Lake Wheeler Road in Raleigh, N.C. The reunion is open to all club or departmental alumni and their families.

The two-day event will kick off at 9 a.m. Friday with the annual Club Day Livestock Show. Club members will show horses, swine, sheep, and dairy and beef cattle throughout the day. Following the show, participants will have a BBQ dinner, followed by entertainment from the Carolina Road bluegrass band. Saturday morning will bring a continental breakfast and the opportunity to tour the Lake Wheeler Road field labs.

If you are interested in joining the alumni registry, contact the club at NCSU Animal Science Club, Box 7621, 102 Polk Hall; Raleigh, N.C. 27695-7621, or via email at ansclubalumni@excite.com.

—Dale Miller
the farm through a reversible chemisorption system for extraction of ammonia. The extracted ammonia is processed centrally into commercial-grade fertilizer. Partially dried feces are also shipped to this central processing facility for energy recovery.

A schematic overview of the RE-Cycle system is shown in Figure 1, and a more detailed description of each of the steps in the system is provided below.

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 for the poultry waste 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 such that the urine runs away from the feces.

Typical behavior of pigs is to defecate against 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 with a width of approximately 2 m 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 2). 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, 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.

For an optimal climate 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 be volatilized. Ammonia has a negative effect on animal and worker health and well-being and has been implicated in eutrophication. 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/pen were 2-3 ppm. A benefit of removing urine from the building is a marked reduction in odor as odor is linked to aging urine. In experiments with the belt, the improved air quality has resulted in a 5% improvement in feed efficiency compared to animals in conventional facilities.

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 it 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 simple. Pigs are asleep most of the night and thus don’t urinate. During this time the feces dry. During the day, the pigs urinate decreasing the dry matter content of the feces. Harvesting feces at 6 am has proven very effective, with dry matters averaging 53%. 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.

In summary:
- Feces are collected at approximately 53% dry matter
- Urine is continuously removed from the house
- Odor and ammonia emissions are minimized
- Belt systems are easy to construct and allow for multi-story swine housing systems
- Belts offer environmental benefits on farms of all sizes

**Steam reforming gasification and liquefaction**

Steam reforming 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$_2$, and CH$_4$, and ash containing minerals. A benefit of this process is that any bio-active compound, such as antibiotics, prions, or viruses, should be destroyed.

The steam reforming gasifier used for research at NCSU uses an entrained flow principle. The swine feces are injected into a spiral tube while suspended by superheated steam and some recycled product gas (Figure 3). This tube surrounds an intense flame, and while traveling up this tube the material is heated to 800°C and decomposes. The reason for co-injecting product gas is to propel the material through the tube. Steam is injected so it can react with fecal material resulting in H$_2$ production. In principle, the reaction occurring is as described below. In practicality, other product gases such as CO$_2$, CH$_4$, H$_2$S, and NH$_3$ are formed as well.

$$C_2H_5O + H_2O \rightarrow 2CO + 3H_2$$

At the exit of the decomposition tube, the product gas is separated from the mineral ash using cyclones and gas cleaners. The product gas has a combustion value similar to low grade natural gas and can be used to fuel a generator or micro-turbine for the production of electricity. This is only a viable option if a market is available for electricity.

Another possibility is to catalytically recombine these gases to produce products such as ethanol or diesel. This is typically achieved by compressing the gases and injecting them at a high temperature into a matrix of, for example, molybdenum sulfide for the production of ethanol or iron silicon dioxide for the production of diesel. This option is technically and financially (higher investment) more challenging but as fuels are produced that can be stored and transported, it may be the preferred option in situations where there is no market for electricity.

The steam reforming gasifier does not require external energy for its operation. Instead, a portion of the product gas or, in the case of catalytic conversion of product gas to

![Figure 3. Belt setup in a conventional, partially slatted, swine house. A polypropylene belt is placed at 40° angle in the pit such that urine runs off into a collection pipe, while feces stay on the belt and dry passively. Feces are collected daily at 6 am at a dry matter content of approximately 53%. Benefits of separating urine and feces are a dry fecal waste stream and substantially reduced ammonia and odor emission.](image-url)
liquid fuels, unreacted product gas, is used to fuel the burner that generates the heat to sustain the process. Thus, the entire process is self-sustaining and equally important, the process does not produce any air emission of noxious compounds such as dioxins.

In summary:
- Any dry organic material, including swine feces, can be converted to electricity or a liquid fuel
- The process does not produce harmful emissions
- The only byproduct is a sterile ash well suited for use as a mineral supplement in swine feed

Recycling of ash

Using grower feed as a starting point, approximately 15% of the feed mass is converted to dry swine feces. Upon steam reforming gasification, approximately 13% of the fecal mass is converted to ash. Thus, per kg of grower feed 20 grams of ash are produced, or 2%. This ash contains most of the minerals that were in the swine feces in either oxide or carbonate form. Exceptions are sulfur, chloride, and nitrogen, which are trapped in the wash liquid of the product gas. 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. Sodium (2.8%) and potassium (12.2%) are mainly excreted in the urine and they are not the predominant minerals in 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. Thus, the RE-Cycle system is expected to not have a significant net surplus or deficiency of phosphorus.

In summary:
- Ash from gasification contains high levels of calcium and phosphorus, which is highly digestible, making it a suitable mineral source for swine
- The ash produced in the RE-Cycle system matches the requirement for inorganic phosphorus of the pigs that are part of the RE-Cycle system

A description of the system for recycling nitrogen, the business model for the entire system, and an economic assessment will be included in the upcoming issue of swine news. Additional information about this system is also available at the MARK website of NCSU under http://mark.asi.ncsu.edu/Waste/Manure/wasteman.htm.

–Theo van Kempen