A Swine Integrator's Perspective on Nutrient Management Procedures[1]

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ABSTRACT: The goal of pork producers is to operate in a sustainable manner that includes among other requirements, environmental soundness, social acceptability, and profitability. Gains in efficiency have reduced nutrient by-products per pig, but competitive forces have led to specialization, larger farms, and concentrated areas of production that have resulted in new opportunities related to nutrient management. Available technology uses on-farm processing or storage facilities, and manure is applied to the land as an organic fertilizer. Knowledge of nutrient content of soils and crop uptake of nutrients is incorporated into manure application and crop removal plans to prevent either runoff or nutrient buildup on the land. This is to ensure water quality protection. Existing systems are adequate but lack flexibility, require effective management, may not have been incorporated into older farms, and do not offer obvious solutions to odor concerns. Cost-effective alternatives should address those needs. Advancement in nutrient management procedures will likely accelerate the ongoing changes in the structure of the swine industry.

Key Words: Pigs, Nutrient Improvement, Manures, Management

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Introduction

The evolution of agriculture has been driven by competitive economic, social, and political forces toward increased specialization. Within the swine industry, specialization has resulted in a worldwide shift from extensive outdoor production to the use of confinement rearing systems. Adoption of new technology, refinement of production systems, and economies of scale have resulted in concentration of swine production and the growth of integrated production. Today, larger farms are being constructed near key infrastructure facilities.

In contrast with pasture or range production systems, modern housing systems are designed for improved animal care and safe management of nutrients in manure. Swine production is not a source of increased manure nutrient production because dramatic improvements in utilization of feed have reduced the excretion of nutrients per pig, but larger farms have resulted in a concentration that has increased the focus on the industry and provided new opportunities for nutrient management techniques.

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Current Situation

The goal of pork producers is to operate in a sustainable manner. Components of sustainability include, among others, requirements for environmental soundness, social acceptability, and profitability.

The total number of hogs produced in the United States has not changed dramatically in the past 50 yr, and concentration of the production capacity into fewer producers has been underway since the early part of this century (Table 1). The industry has been generally located close to areas of efficient grain production (Table 2), but concentrated areas of pork production exist around the world that do not coincide with areas of grain production. The Netherlands, Denmark, parts of the United Kingdom, and the mid-Atlantic region of the United States are a few examples. From a global perspective there are fewer by-product nutrients per pig because of enhanced efficiency, but due to a concentration of production capacity into fewer producers, nutrients are more concentrated in certain locations. Modern production systems have incorporated components to provide an environment for the pigs that will ensure comfort and support efficient production and proper handling of manure to protect the environment.

Existing Technology

From a nutrient management perspective, the swine industry is primarily concerned with systems to

Table 1. Production of hogs in the United States[a]

Year	Number of hogs	Number of farms
1900	62,879,000	4,335,989
1920	59,350,000	4,852,430
1940	34,040,000	3,767,875
1950	55,720,000	3,013,549
1960	59,030,000	1,848,784
1965	50,519,000	1,057,570
1975	49,267,000	661,700
1985	52,314,000	388,570
1993	56,798,000	235,840

[a]Data from Brandt et al. (1985) and USDA (1988–1994).

protect water quality. Modern pork production uses a wide variety of facilities. However, they have similar components or features to achieve effective nutrient management. Pen flooring is slatted or a woven material designed to allow waste to fall through. Space below the floor is used for manure storage in some systems. In others, a method for the frequent removal of manure from the building to a storage and processing facility prior to application as a fertilizer is provided. Usually, waste is removed from the building by flushing with water recycled from the storage and processing facility or by a mechanical scraper system. Features of the storage and processing facility are influenced by a number of factors, including soil type, climate, and the crop production system that will use the nutrients. Material from the storage facility is periodically sampled to determine nutrient content and applied to the land as organic fertilizer. Frequency and volume of application must coincide with crop production and harvesting to achieve effective nutrient removal from the soil and to avoid surface run-off. Excessive soil nutrient accumulation must be avoided to prevent contamination of ground water.

Adequate knowledge of land application sites is required to complete nutrient management plans. Soil types, existing nutrient concentrations, topography, erosion potential, crop productivity potential, and crop systems must be considered to determine appropriate application rates. Timing of application should coincide with nutrient utilization by the crop. Soil sampling schemes are developed based on soil type and topography (Figure 1). Results of soil analyses and crop plans form the basis for application recommendations (Table 3).

As described here, the technology is available for concentrated production of swine and management of nutrients in manure to protect water quality. Swine integrators have refined the management of these systems to provide greater environmental protection by their management focus. Government regulations are now incorporating these refinements and, thereby, require all swine producers to adhere to design and management criteria that represent today's best practices. Examples include the use and monitoring of depth gauges in manure storage and processing facilities to avoid overflow, records of land application rates, and records of crop removal. Without doubt, no other agricultural, livestock, or crop production industry begins to approach the level of basic technical knowledge, operational control, and monitoring capability that is available to the swine industry to protect water quality.

Challenges

A report to the North Carolina General Assembly identified nitrogen and phosphorus as nutrients with the greatest potential to adversely affect water quality as a result of swine production operations (Swine Odor Task Force, 1995a). If concentrations of nitrate nitrogen reach high levels at depths below the root zone of plants, nitrate may leach into ground water. Surface water contamination by nitrate nitrogen can occur with runoff from over-application. The solubility and, therefore, mobility of phosphorus in soils is much less than that of nitrate nitrogen. The threat to ground water from phosphorus is minimal, but transport to surface water can occur from direct runoff or erosion of soils.

There have been instances of poorly managed or improperly operated systems. Inadequate systems are more common in older facilities, and these systems generally require increased management. Poor management presents the greatest potential for failure of nutrient handling systems. The most extreme event would be overflow of the storage facility. More subtle danger comes during land applications. Over-application, improper timing, failure to maintain crop systems, and application during a rainfall can result in runoff. In many integrated swine production systems, the job has been assigned to teams of specialists whose only responsibility is the proper

Table 2. Production of hogs in the United States by region.[a]

Region	1970	1994
	Percentage of total production	
Eastern corn belt (OH, IN, IL, MI, WI)	28.6	23.3
Western corn belt (MN, IA, MO)	37.2	37.7
Northern plains (ND, SD, NE, KS)	13.7	12.8
Southeast CAR, LA, KY, TN, MS, GA FL, SC, NC, VA, AL)	14.4	19.3
Southwest (TX, OK, NM)	2.6	1.9
Other	3.5	5.0
48 Contiguous states total	100.0	100.0

[a]Data from National Agricultural Statistics Service (1993).

operation and management of those systems. This effectively reduces risk associated with operational aspects by providing training, focus, and accountability.

Seepage can possibly occur from old storage facilities constructed in coarse soils without liners of clay or other material (Swine Odor Task Force, 1995a). Those same studies confirmed the safety of current design standards, and particularly the effectiveness of clay liners. Therefore, the potential for contamination of water from lagoon seepage has been greatly reduced in new facilities, but it is of concern for certain older farms. In some locations, a key environmental concern is fresh water requirements to operate large-scale production facilities. Water is obviously necessary for hogs. Also, substantial volumes of water are used in cleaning the facilities.

Today's technology is effective but has limited flexibility because of fairly specific requirements for the appropriate combination of factors related to soil type, climate, amount of land required, cropping systems, and so on. Swine manure contains high levels of water, and the nutrient content is extremely dilute compared with concentrated commercial fertilizers. High moisture content and low nutrient concentration of material removed from storage facilities makes it expensive to store, transport, and apply on the land. Because of this, most land application is in close proximity to the swine production unit. The need for nearby land for application of wastes often limits expansion and modernization of existing facilities. This will limit the ability of the industry to lower production costs in order to compete in the marketplace. This is particularly true for older operations, which tend to be smaller.

Perhaps the most critical issue facing the industry is odor. Odor has always been a product of livestock enterprises, but larger farms, new development, and migration of people from urban to rural residences have combined to intensify the problem. The production of odor, source of odor, and human response to odor are extremely site-specific (Swine Odor Task Force, 1995b). Inability to measure odor, quantify thresholds, or clearly define the problem make it difficult to develop strategies toward solutions. Public objections to odors from swine operations generally focus on property values and quality of life issues.

Outlook For The Future

With the goal of sustainability, we will continue to encourage the development of alternatives to the basic technologies employed in our current systems. Efforts should continue to reduce excretion of nutrients of greatest concern. Improved productivity is the most obvious strategy. Continued genetic progress to enhance the efficiency of production of high-quality lean meat is essential. Increased reproductive efficiency will play an important role.

Nitrogen excretion can be substantially reduced by a number of other strategies including formulation of diets to precisely meet amino acid requirements, and formulation of diets with synthetic amino acids to

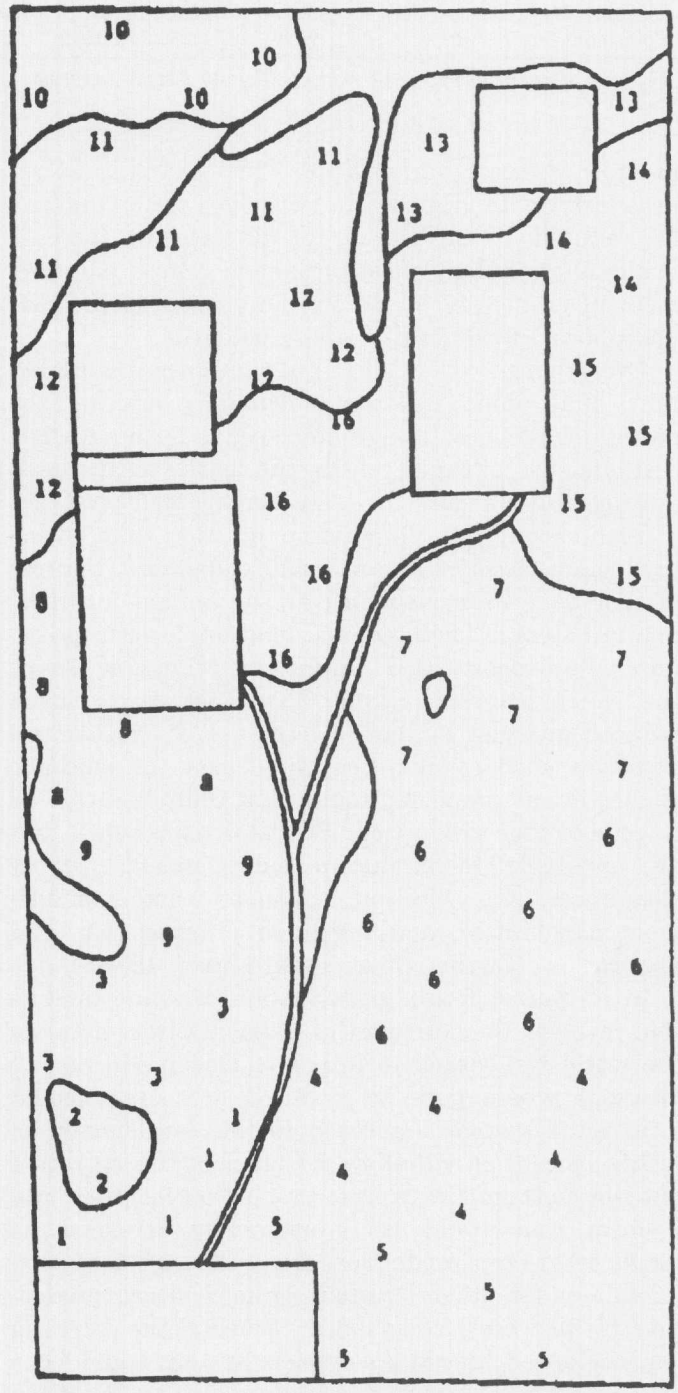

Figure 1. Example of soil sampling map from a commercial sow production facility. Numbers 1 through 16 indicate location from which sample was obtained. Samples from locations with the same numbers were combined to provide a composite. Unpublished data from Murphy Family Farms.

Table 3. Example of recommended application of aerobic swine lagoon effluent[a]

Item	Locations									
	1	2	3	4	5	6	7	8	9	10
Applications/yr	2	1	1	1	1	1	2	3	2	2
Volume, cm/ha	1.3	1.3	1.9	1.3	1.3	.65	1.3	1.3	1.3	1.3
Nutrients applied										
Nitrogen, $kg \cdot ha^{-1} \cdot yr^{-1}$	257.6	128.8	192.6	128.8	128.8	65.0	257.6	386.4	257.6	257.6
Phosphorus, $kg \cdot ha^{-1} \cdot yr^{-1}$	51.5	25.8	38.0	25.8	25.8	19.0	51.5	77.3	51.5	51.5
Potassium, $kg \cdot ha^{-1} \cdot yr^{-1}$	25.8	13.4	19.0	13.4	13.4	17.9	25.8	39.2	25.8	25.8

[a]From unpublished data of Murphy Family Farms research.

provide essential amino acids while avoiding excess protein is another approach. Phosphorus excretion can be reduced by utilization of phytase to increase availability of plant phosphorus, and genetic enhancement of grains and plant protein sources to increase phosphorus availability offers potential.

Even though reduction in nutrient output is important, that alone will not adequately address the current challenges. The greater need is for innovative, cost-effective alternatives to the basic technologies employed in our current waste management systems.

Technologies for elimination of odor from swine production facilities are not readily apparent. Sources of odor have been identified as the animal facilities, manure storage facilities, and land application procedures. In a report titled "Options for Managing Odor," the North Carolina Swine Odor Task Force listed reduced nitrogen content of feed, use of odor control additives such as enzymes, and biogas or methane generation as promising topics that could be explored to reduce odor production. Practical approaches that are available to producers today include proper cleanliness, site selection, adequate waste management capabilities, and improved practices for land application (Swine Odor Task Force, 1995b).

In its purest form, specialization of swine production involves the transport of nutrients from areas of the world well-suited to intensive feed production to locations where pork is produced. Research should focus on a systems approach to the development of technologies that will allow the efficient concentration of by-product nutrients from production facilities into a form that could be economically returned as fertilizer to crop production areas or used as a feed ingredient for other livestock or agriculture production. If this were accomplished, closure of the recycling loop could be achieved. An efficient system would focus on nutrient retention in the final product to maximize fertilizer value. The key will be to efficiently capture nutrients, especially those containing nitrogen, from the water fraction. The swine farm of the future could incorporate solid separation, filtration, or other strategies to produce a concentrated organic nutrient by-product.

It will be important to design future production systems to reduce water input into the waste stream. This will serve to lower the total farm water requirements and reduce the requirement for removal of water in order to achieve efficient concentration of nutrients. Progress in this area could reduce the requirement for large-capacity on-farm facilities for manure storage and treatment, drastically reduce on-site land requirements, and result in truly effective options for odor reduction. Without a fundamental shift in waste management capability, we will begin to see the removal of production capacity because of limited land available for nutrient application in some locations.

Because of the complex nature of the challenges, interdisciplinary efforts will be needed to accomplish the development of truly effective alternatives developed with the input of representatives of disciplines that have not traditionally focused on agricultural waste systems, including microbiology, chemistry, and chemical and mechanical engineering. Academic institutions should examine organization and funding structures with the goal of focusing available resources appropriately. Today the most innovative approaches are emerging from the private sector. Examples include tangential flow separation, filtration, ultrafiltration, and advanced aeration techniques. Integrated producers are facilitating technology development by installing the alternative systems in newly constructed facilities, providing input for system modifications to improve functionality in the context of requirements to achieve efficient animal performance, and conducting economic assessment.

The swine industry will remain focused on the goal of sustainability. Environmental concerns will influence the evolution of our industry and economic implications will increase. Advancement in nutrient management methods could help solve challenges with outdated facilities, but it most likely will hasten their demise in favor of units that incorporate modern processes. In order to deal with odor concerns, production units might be moved to sparsely populated regions. New processing systems might dictate the construction of facilities in large geographically self-contained units in order to use a central processing facility.

The future will need to be addressed with open minds and a continued commitment to the environment. The swine industry has adapted and will continue to adapt to the requirements necessary to protect the environment and must insist that change is driven by facts rather than emotions. Pork producers will continue to refine existing technologies and management capabilities and encourage development of new technology and the applications of technologies that are not currently used in agricultural systems to achieve more efficient and economical methods of safe and effective nutrient management.

Implications

Specialization has led to larger farms and concentrated areas of production and provided new opportunities for the use of by-product nutrients. Technology is available to protect water quality and allow for the concentrated production of pigs; however, existing systems lack flexibility, have substantial management requirements, and do not offer obvious solutions to odor concerns. Cost-effective alternatives to the basic technologies might address those issues. It is likely that advancement in nutrient management methods will accelerate the ongoing consolidation in the structure of the swine industry.

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