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Economic feasibility and evaluation of a novel manure collection and anaerobic digestion system at a commercial swine finisher enterprise

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ABSTRACT

A case study conducted at a commercial swine-finishing farm demonstrated that a novel manure management system increased economic feasibility of an anaerobic digester by eliminating the need for post-digestion manure storage construction at the farm. Uniquely designed underfloor manure storage pits collected manure for delivery to the digester, and then stored post-digested manure (digestate) in underfloor storage within the same swine houses. It was unknown if the introduction of biologically active digestate into these pits would produce pig living space air quality that was adverse to pig health, growth or survival, or if explosive methane levels would be generated within the buildings. Monitoring of air quality indicators both before and after digestate introduction to underfloor manure storage pits resulted in no observations of hydrogen sulfide (H_2S) or methane (CH_4) concentrations above critical safety levels in swine housing. Hourly mean ammonia (NH_3) concentrations at pig level (0.15 m above the floor) before digestate was present in the buildings were higher ($P < 0.05$) compared to when digestate was present (24 ± 2.8 ppm vs. 17 ± 1.0 ppm). Air quality measures did not indicate that digestate introduction into underfloor manure pits caused degradations of air quality at pig level. No obvious etiologic effects on swine were observed. Evaluation of the electric cogeneration system showed that cost-savings of electricity produced from biogas combustion was approximately equal to the producer's debt service for capital investment. External funding and low interest financing were necessary for electric cost-savings to offset finance payments.

1. Introduction

Anaerobic digestion of manure produces methane-rich biogas that can be combusted in an engine-generator system to produce electricity to offset farm electricity purchase. Widespread adoption of anaerobic digestion technology has not occurred because of high capital investment and nominal economic return [1–3]. The competitiveness of biogas with other fuels used for heat or combined heat and power is limited [4]. Rising social costs associated with environmental impacts, energy use, and manure odor generation make

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manure digestion attractive. Anaerobic digestion may become more affordable as advances in technology, lower capital investment requirements, and rising costs of non-renewable fuels make biogas systems more economically reasonable [5]. One method to avoid capital cost of digestate storage in a standard commercial swine-housing unit with under-barn manure storage would be to segregate standard underfloor manure storage volume into compartments of pre- and post-digested manure volumes. These specific compartments could be located directly below pen space dedicated to lying and dunging that arise because pigs rest near pen perimeters [6] and dung in open spaces [7] away from resting areas [8]. It was not clear whether underfloor digestate manure storage would provide sufficient amounts of raw manure for the practical operation of an anaerobic digester.

The objectives of this case study were; 1) Quantify the proportion of manure deposited into compartmentalized manure collection pits located under observed dunging areas; 2) Determine economic feasibility of this novel design by evaluating investment expenses, biogas production and electricity production over a two-year steady-state; 3) Compare swine house air quality before and after the introduction of digestate; 4) Compare manure constituents before and after digestion; 5) Compare growth performance and death loss for pigs in houses with underfloor digestate to that of pigs in control barns.

2. Materials and methods

2.1. Dunging pattern and manure pit depth analysis

The underfloor storage pits in each of two large-pen swine finishing buildings were modified to advantageously collect manure deposited in dunging areas found in the central location of the large pens of the buildings (Fig. 1). Each building housed about 2200 hogs in four large pens equipped with self-sorting technology on totally slatted floors. The pens were located in two rooms (two large pens per room) within each building (1100 pigs room^{-1}, 550 pigs pen^{-1}). The rooms were equal in size and mirrored one another with location of feeders, waterers, scales, penning, and ventilation; the only exceptions were worker walkways located along an end-wall. The adjacent 85.3 m long and 24.4 m wide buildings near Danville, Pennsylvania, USA, were simultaneously constructed in 2002 by Schick Enterprises (Kutztown, Pennsylvania, USA). The rooms were tunnel-ventilated with static-pressure controlled air inlet curtains. Five manure pit fans were spaced evenly along each long wall of the buildings. Pit fans were functional for only part of the study time frame.

Located under dunging areas in each room, underfloor manure pits were configured to collect a majority of manure deposition and to remove that manure to an anaerobic manure digestion treatment system (Fig. 2). Once treated, manure returned from the digestion vessel to the manure pits located under the lying areas, termed return pits. Thus five manure pits of equal depth represent two separate manure storage classifications within each building, each located beneath 12.19 m of building width. Manure depth of the two or three pits within a storage classification were equalized by

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b

Fig. 1 – Lying and dunging behavior. Two photos demonstrating swine lying and dunging pattern in large, totally slatted pens. Pigs lie along the perimeter and dung in the central area of the pens. Because of the rectangular pen shape the dunging areas were long and narrow.

25 cm diameter open pipes that connected the pits and were located near the center of the pit length and under the floor concrete (Fig. 3). Most feeders and swinging waterers in the houses were located above the collection pits to direct waste feed and water to the digester. Fig. 4 demonstrates manure flow. A schematic diagram of the large-pen swine finishing building with self-sorting technology is presented in Fig. 5. All penning contained ad libitum access to feed and water.

Because the two underfloor manure systems were roughly equal in volume, changes in depth were used to determine the percentage of manure deposited into each system. These measures were conducted prior to operation of the anaerobic digester. No data were collected when volume was influenced by removal of manure for field application. Buildings were unpopulated and washed after marketing of hogs. Because this was representative of normal commercial operation, manure depth measurements over these periods were maintained and wash water included in manure volume changes.