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On-farm Anaerobic Digester: Frequently Asked Operation, Maintenance, and Safety Questions

Mahmoud Sharara

During and after the first offering of the Animal Waste Biogas Digester Operator Training (Kenansville, 10/11/2024), we received the following questions. A panel of experts was invited by Amanda Hatcher and Mahmoud Sharara to a Zoom conference call to provide their perspectives answering these questions. Panelists reviewed their answers before publication (panel participants are listed below in alphabetical order).

Prince Dugba, Director of Science and Technology, Monarch Bioenergy, LLC
Amanda Hatcher, Duplin County Extension Director
Christine Lawson, Engineer, Division of Water Resources
Mahmoud Sharara, Associate Professor and Extension Specialist, NC State University
Gus Simmons, Director of Bioenergy Services, Cavanaugh & Associated, P.A.
Kevin Weston, Environmental Resource Specialist II, Smithfield Hog Production

Operation and Maintenance

Why are digesters designed for 40 days of treatment? And what happens to the manure afterwards?

In North Carolina, digesters are built with treatment volume equivalent to 40-day worth of manure volume. If you do not provide additional heat, the 40-day period is the amount of time needed for digester bacteria to convert most manure carbon into biogas. This period can increase or decrease depending on where you are; a warmer climate means a shorter period and vice versa. So, on any given day, as manure is being fed into the digester, an equivalent volume flows out from the opposite end as a digestate and enters the secondary lagoon. If operated correctly, the digestate leaving the digester has spent 40 days inside the digester.

How do you prevent liner damage during sludge removal? What does the owner need to ensure/consider for this process?

It is recommended the farm owner hires a contractor with experience removing sludge from plastic-lined structures. The farm owner needs to provide the sludge removal operator with a clear design plan showing depth, side-slopes, and any internal parts that may interfere with pumping.

From the perspective of the project developer, how could you judge that the digester is working the way it is supposed to?

There are three factors that we look for to make sure the digester is working properly. First, gas production needs to remain close to expectations based on time of year, and where animals are in their growth cycle. We track gas production through the amount of cover inflation. The second factor we look at is the concentration of methane in the gas. It needs to be at or greater than 65% of the gas volume, based on our experience. Finally, we look at the relative amount of volatile fatty acids to alkalinity to ensure it is below 0.3. This ratio tells us whether the digester operation is stable or it could suffer from acidic pH. A low pH in the digester reduces gas productivity or completely stops it. We also track the amount of total solids in the manure entering the digester compares to total solids leaving the digester. We found the swine manure in NC has a wealth of alkalinity, and thus, acidifying a digester not to be concern. From a business perspective, we are always looking for opportunities to optimize operations to increase efficiency and profitability.

How often would a grower with this system evaluate how the digester is behaving?

This differs depending on the details of the contract between the farm owner and the developers. Often, developers specifically spell out the responsibility for tracking performance and developing benchmarks. Tracking performance by sampling and data analysis is critical to detect if performance is lagging and to develop corrective action plans.

What happens to the sludge in the lagoon after I install a digester?

On farms where the existing lagoon is covered, we remove sludge first. On farms where a new digester will be built, we proactively collaborate with farmers to help them desludge the lagoon and find options to turn it into organic fertilizer. It is critical to do so economically to avoid financial burden to the producer. We do what we can to minimize sludge from accumulating in the new digester. We anticipate the existing lagoon to see the sludge accumulation stay the same or slightly decrease but we do not have a long track record of data to have a conclusive answer. We also try to design and construct new digesters to have additional access points, as well, that we hope will aid in future sludge removal. It is early to know exactly how sludge in the lagoon shifts after a digester is installed before it.

How often do I need to clean the digester sludge?

We use digester performance to guide the frequency of sludge removal. We found the smaller the digester, the sooner you may need to remove sludge. We typically include in the design some sludge storage volume but work to reduce its accumulation. Depending on the size, location, and design, a digester may need cleanout once per year to once every 20 years. More often, it is a 5 to 10 year time-horizon between cleanouts. We observed that more frequent sludge removal that are of smaller volumes are easier for most farmers to incorporate into their nutrient management plans, and recommend this approach. We typically look to NRCS technical standards for recommendations on sizing and operation of digesters (Code NRCS CPS 366). This standard includes a minimum retention time to ensure proper operation. The economics of the digester operations will dictate the sludge removal much more urgently than any regulatory requirements. We are seeing digester designs submitted for permitting that include a volume for sludge storage in the digester.

Will I need to remove the digester cover to remove the sludge?

We require digester designs submitted for permitting to include plans showing how sludge will be removed. There is no regulatory requirement on which option is used to manage sludge. Some meet this requirement by installing pipes at the bottom of the digester that allow for pumping sludge without removing covers. Others indicate they will cut part of the cover to gain access to the digester content to remove sludge then repair it to resume operations. There are different scenarios for sludge removal from covered lagoon digesters, but possibly yes. In cases where the digester is accessed through the cover, it is opened then resealed afterwards. In cases where pipes are installed inside the digester, there is no need to open the cover. These digesters need to be graded correctly to ensure solids can be removed easily. In cases where digesters are equipped with under-pipes, sludge can be removed more frequently; possibly once a year.

I am having problems with salt buildup in my pipes and lines; will installing a digester help/hurt with this issue?

These salts are the result of ammonium, phosphate, and magnesium fusing and forming salts (struvite). While adding a digester does not increase the amount of nitrogen and phosphorus in the slurry, concentration of ammonium and phosphate increases. The formation of salt buildup (in particular struvite) may stay the same or increase but we do not have enough data support this claim. Salt buildup provides an opportunity to install nutrient recovery systems to harvest ammonium and phosphorus as struvite and distribute off-farm as a byproduct.

Where does the phosphorus in the manure go; does it stay in the digester or pass along to the lagoon?

Phosphorus generally follows the solids. After adding a digester, solids will start to build up in the digester until the sludge is removed. So, when digester routine cleanout is performed, the sludge will contain that phosphorus.

Where should I dispose of the rainwater that collects on the lagoon cover?

In the digester designs we receive, we expect to see details of the rainwater removal system. This includes where rainfall will collect on the cover, the pumping system, and an outlet that will convey water without risk of erosion or structural damage. The pumped water could be discharged in a grassed area. A critical requirement is that the operator ensures the pumped rainwater does not contain waste leakage from the digester. In cases of one or more inches of rainfall, the operator is required to inspect the facility (the same requirement existing in the state general permits for animal operations without digesters). As part of that inspection, they need to ensure the rainwater pumping system is operated and that it is not mixed with manure or digester contents. We have not seen any cases where the digester contents were mixed with the rainwater pumped off the cover. We expect as the covers age or sustain damages that they may become a contamination risk to rainwater and should therefore be inspected before decanting the rainwater from the cover. This rainwater system can be manual or automated. We are trying to move towards automation, so we are designing these systems to kick in at a certain rainfall depth to pump rainwater out through the outlet to a grassed area on site. Operators still need to observe and look for any signs of waste mixing with rainwater.

What happens if a very heavy rain (22 inches or more) falls on top of the cover?

We learned from past experiences that with proper design, and a seal weld between cover and liner, we can isolate rainwater and swine effluent under heavy rainfall conditions. Some digesters are built without a weld between cover and liner; these digesters could present a risk of digester content leakage under heavy rainfall. In cases of extreme events, the rainfall pump system is unlikely to keep up with the high rainfall rate. While there is some capacity to store some excess rainwater on the cover, this capacity could soon fill to the point of overflowing the top of the digester embankment. To prevent erosion or structural damage, a second line of defense could be a spillway, to allow this excess rainwater to get off the cover quickly and safely.

What if a power outage takes place when rainwater needs to be removed?
We have not seen situations with new digesters where power failures were an issue on site. Once power is run to the site, the system works well. We are not aware of issues of not being able to pump rainwater off cover. Most farms have a backup generator on site to ensure continuous feed, and water delivery to the pigs. It is advised to address this during the planning and design stages to add the rainwater pumping to the backup generator capacity. Another point to keep in mind is that farmers also keep non-electric pumps on site which could be utilized to get rainfall off the cover under power failure. Keep in mind that during hurricane conditions, you would want to first lower the digester cover then keep some water standing on the cover. This will help protect it from wind damage. But leaving too much water standing on the cover may compromise the structural integrity of the digester.

<u>Safety</u>
What is the safe distance from a digester when a fire happens?
Project insurance requires a clear idea on this distance around the site. For fire to spread, methane needs to be at least 5% of the air volume. When we did our analysis we found that 20 feet from the source of the leak is enough to dilute the methane and eliminate spread. Most methane leakage we see are pinhole discharges of methane. As a result, we require operators to wear gas detectors and monitors if they are within 100 feet. Ditto Christine's comments about signage for farms. NRCS standard requires flares be a minimum of 50 feet from source. 100 feet is a conservative approach. Wearing monitoring devices is important and posting signage regarding the risks on farms is very important to reduce the fire risk. Signs need to be posted at the entrance of the facility and in proximity of the structure.

How close can a residence be located to a digester without having safety concerns?
From a regulatory perspective, the Swine Farm Siting Act applies to digesters. In it, digesters, much like barns or lagoons, must be at least 1,500 feet from residences not owned by the farm owner. For a swine farmer that owns a home on the farm, while they are exempt from this regulatory requirement, using this distance as a guideline is advised to ensure safety to persons and property.

For additional information, visit our Manure Anaerobic Digester webpage.

Preguntas Sobre Operación, Mantenimiento, y Seguridad

Translation by: Eduardo Beltranena

Preguntas sobre Operación y Mantenimiento

¿Por qué los digestores están diseñados para 40 días de tratamiento? ¿Y qué pasa con el estiércol después de eso?

En Carolina del Norte, los digestores se construyen con un volumen de tratamiento equivalente al volumen calculado de estiércol de 40 días. Si no se proporciona calor adicional, el período de 40 días es el tiempo necesario para que las bacterias del digestor conviertan la mayor parte del carbono del estiércol en biogás. Este período puede aumentar o disminuir dependiendo de la ubicación. Un clima más caliente significa un período más corto y viceversa. Entonces, en cualquier día, a medida que el estiércol se introduce en el digestor, un volumen equivalente fluye hacia afuera por el extremo opuesto como digestato y entra a la laguna secundaria. Si se opera correctamente, el digestato que sale del digestor ha pasado 40 días dentro del digestor.

¿Cómo se previene el daño al revestimiento durante la remoción de lodo? ¿Qué debe asegurarse o considerar el propietario para este proceso?

Se recomienda que el propietario de la granja contrate a un contratista con experiencia en la remoción de lodo de estructuras revestidas con plástico. El propietario de la granja debe proporcionar al operador de remoción de lodo un plan de el diseño del digestor que muestre claramente la profundidad, las pendientes laterales y cualquier parte interna que pueda interferir con la operación y movimiento de la bomba.

Desde la perspectiva del desarrollador del proyecto, ¿cómo se puede juzgar si el digestor está funcionando como se supone?

Hay tres factores que debemos observar para asegurarnos de que el digestor esté funcionando correctamente. Primero, la producción de gas debe mantenerse cerca de las expectativas basadas en la época del año y la fase del crecimiento de los animales. Seguimos la producción de gas a través de la cantidad de inflamiento de la cubierta. El segundo factor que analizamos es la concentración de metano en el gas. Debe ser del 65% (~2/3) o más del volumen de gas, según nuestra experiencia. Finalmente, observamos la cantidad de ácidos grasos volátiles en relación a la alcalinidad para asegurarnos de que esté por debajo de 0.3. Esta proporción nos indica si la operación del digestor es estable o si está sufriendo de un pH ácido. Un pH ácido en el digestor reduce la productividad del gas o la detiene por completo. También comparamos la cantidad de sólidos totales en el estiércol que entran al digestor con los sólidos totales que salen del digestor. Hemos descubierto que el estiércol porcino en Carolina del Norte tiene una gran cantidad de alcalinidad, por lo que la acidificación de un digestor no es una preocupación. Desde una perspectiva empresarial, siempre buscamos oportunidades para optimizar las operaciones y aumentar la eficiencia y rentabilidad.

¿Con qué frecuencia debe un productor evaluar cómo opera el digestor?
Esto varía según los detalles del contrato entre el propietario de la granja y los desarrolladores. A menudo, los desarrolladores especifican claramente la responsabilidad de realizar el seguimiento del desempeño y desarrollan indicadores de referencia. El seguimiento del desempeño mediante muestreo y análisis de datos es crucial para detectar si el rendimiento está rezagado y hay necesidad de desarrollar planes de acción correctivos.

¿Qué pasa con el lodo de la laguna después de instalar un digestor?
En las granjas donde la laguna existente está cubierta, primero retiraremos el lodo. En las granjas donde se construirá un nuevo digestor, colaboraremos proactivamente con los agricultores para ayudarles a eliminar el lodo de la laguna y encontrar opciones para convertirlo en fertilizante orgánico. Es crucial hacerlo de manera económica para evitar una carga financiera adicional para el productor. Haremos todo lo posible para minimizar la acumulación de lodo en el nuevo digestor. Anticipamos que la acumulación de lodo en la laguna existente se mantendrá igual o disminuirá ligeramente, pero no tenemos un historial largo de datos para tener una respuesta concluyente. También tratamos de diseñar y construir nuevos digestores con puntos de acceso adicionales para que ayuden en la remoción de lodo en el futuro. Es todavía preliminar para saber cómo exactamente el lodo en la laguna cambia después de instalar un digestor.

¿Con qué frecuencia debo limpiar el lodo del digestor?
Usamos el rendimiento del digestor para guiar la frecuencia de la remoción del lodo. Hemos encontrado que cuanto más pequeño es el digestor, más pronto puede ser necesario eliminar el lodo. Normalmente incluimos en el diseño un volumen de almacenamiento de lodo, pero trabajamos para reducir su acumulación. Dependiendo del tamaño, la ubicación y el diseño, un digestor puede necesitar limpieza desde una vez al año hasta una vez cada 20 años. Con mayor frecuencia, el horizonte de limpieza es de 5 a 10 años. Hemos observado que la remoción más frecuente de lodo, en volúmenes más pequeños, es más fácil de incorporar en los planes de manejo de nutrientes de la mayoría de los agricultores. Así que recomendamos este enfoque. Normalmente seguimos los estándares técnicos de NRCS como recomendaciones sobre el dimensionamiento y la operación de los digestores (Código NRCS CPS 366). Este estándar incluye un tiempo mínimo de retención para garantizar un funcionamiento adecuado. La economía en la operación del digestor dictará la remoción de lodo mucho más urgente que cualquier requisito regulatorio. Estamos evaluando diseños de digestores para los cuales se han pedido permisos que incluyen un volumen para almacenamiento de lodo en el mismo digestor.

¿Necesitaré quitar la cubierta del digestor para remover el lodo?
Requerimos que los diseños de digestores enviados para obtener permisos incluyan

planes que muestren cómo se removerá el lodo. No existe un requisito regulatorio sobre qué opción se debe usar para manejar el lodo. Algunos cumplen con este requisito instalando tuberías en la parte inferior del digestor que permiten bombear el lodo sin quitar las cubiertas. Otros indican que cortarán parte de la cubierta para acceder al contenido del digestor, eliminar el lodo y luego reparar la cubierta para reanudar operaciones. Existen diferentes escenarios para la remoción de lodo en digestores de lagunas cubiertas, pero posiblemente sí. En los casos donde el digestor se accede a través de la cubierta, se abre primero y luego se vuelve a sellar. En casos donde se instalan tuberías dentro del digestor, no es necesario abrir la cubierta. Estos digestores deben estar correctamente nivelados para garantizar que los sólidos puedan eliminarse fácilmente. En los casos donde los digestores están equipados con tuberías internas, el lodo puede removerse con mayor frecuencia, posiblemente una vez al año.

Tengo problemas con la acumulación de sal en mis tuberías y líneas; ¿ayudará o empeorará esto la instalación de un digestor?

Estas sales son el resultado de la fusión de amonio, fosfato y magnesio, formando sales (estruvita). Aunque agregar un digestor no aumenta la cantidad de nitrógeno y fósforo en el lodo, la concentración de amonio y fosfato aumenta. La formación de acumulación de sales (en particular estruvita) puede mantenerse igual o aumentar, pero no tenemos suficientes datos para respaldar esta teoría. La acumulación de sal ofrece una oportunidad para instalar sistemas de recuperación de nutrientes para cosechar el amonio y fósforo como estruvita y distribuirlo fuera de la granja como subproducto.

¿Dónde va el fósforo en el estiércol? ¿Se queda en el digestor o pasa a la laguna?

El fósforo generalmente sigue los sólidos. Después de agregar un digestor, los sólidos comenzarán a acumularse en el digestor hasta que se retire el lodo. Entonces, cuando se realice la limpieza rutinaria del digestor, el lodo contendrá el fósforo que tiene valor fertilizante.

¿Dónde debo deshacerme del agua de lluvia que se recoge sobre la cubierta de la laguna?

En los diseños de digestores que recibimos, esperamos ver detalles del sistema de eliminación de agua de lluvia. Esto incluye dónde se recogerá la lluvia que se colecta de la cubierta, el sistema de bombeo y una salida que conduzca el agua sin riesgo de erosión o daño estructural. El agua bombeada podría ser descargada en una zona de césped o pasto. Un requisito crítico es que el operador debe asegurarse de que el agua de lluvia bombeada no contenga filtraciones de residuos del digestor. En caso de lluvias de una pulgada o más, el operador debe inspeccionar la instalación (el mismo requisito existente en los permisos generales estatales para operaciones ganaderas sin digestores). Como parte de esa inspección, deben asegurarse de que el sistema de bombeo de agua de lluvia esté operando y que no se esté mezclado con estiércol o contenido del digestor. No hemos visto casos en los que el contenido del digestor se haya mezclado con el agua de lluvia bombeada de la cubierta. Esperamos que, a medida que las cubiertas envejezcan o sufran daños, esto pueda convertirse en un riesgo de contaminación para el agua de lluvia y, por lo tanto, la cubierta debe inspeccionarse antes de vaciar el agua de lluvia. Este sistema de agua de lluvia puede ser manual o automatizado. Estamos tratando de avanzar hacia la automatización, por lo que estamos diseñando sistemas para que se activen a una cierta profundidad de lluvia para bombear el agua de lluvia a través de la salida hacia una zona de césped o pasto en el mismo sitio. Los operadores aún deben observar y buscar signos de mezcla de residuos con agua de lluvia.

¿Qué pasa si cae una lluvia muy fuerte (22 pulgadas o más) sobre la cubierta?
Aprendimos de experiencias pasadas que, con un diseño adecuado y un sellado entre la cubierta y el revestimiento, podemos aislar el agua de lluvia y el efluente porcino bajo condiciones de lluvias intensas. Algunos digestores se construyen sin una unión entre la cubierta y el revestimiento. Estos digestores podrían presentar un riesgo de filtración de contenido del digestor durante lluvias fuertes. En casos de eventos extremos, es poco probable que el sistema de bombeo de lluvia pueda mantener el ritmo con la alta tasa de lluvia. Si bien existe capacidad para almacenar algo de agua de lluvia excedente sobre la cubierta, esta capacidad podría llenarse rápidamente hasta el punto de desbordar la parte superior del terraplén del digestor. Para prevenir la erosión o daño estructural, una segunda línea de defensa podría ser un vertedero, para permitir que el exceso de agua de lluvia se descargue rápidamente y de forma segura en la dirección deseada.

¿Qué sucede si hay un corte de energía eléctrica cuando se necesita retirar el agua de lluvia?
No hemos visto situaciones con nuevos digestores donde los cortes de energía eléctrica sean un problema en el sitio. Una vez que se suministra energía eléctrica al sitio, el sistema funciona bien. No estamos al tanto de problemas de no poder bombear el agua de lluvia de la cubierta. La mayoría de las granjas porcinas tienen un generador de respaldo en el sitio para garantizar la alimentación continua y el suministro de agua a los cerdos. Se recomienda pensar esto durante las etapas de planificación y diseño para agregar la capacidad de bombeo de agua de lluvia a la capacidad del generador de respaldo. Otro punto a tener en cuenta es que los agricultores también tienen bombas no eléctricas en el sitio (PTO), que podrían utilizarse para eliminar el agua de lluvia de la cubierta en caso de un corte de energía eléctrica. Recuerde qué durante condiciones de huracán, primero debe bajar (desinflar) la cubierta del digestor y luego mantener algo de agua sobre la cubierta. Esto ayudará a protegerla del daño causado por el viento intenso. Pero dejar demasiada agua sobre la cubierta debido a su peso puede comprometer la integridad estructural del digestor.

Preguntas sobre Seguridad

¿Cuál es la distancia más segura de un digestor en caso de incendio?
El seguro para el proyecto requiere una idea clara sobre esta distancia alrededor del sitio. Para que el fuego se propague, el metano debe ser al menos el 5% del volumen de aire. Cuando realizamos nuestro análisis, encontramos que 20 pies (6 metros) desde la fuente de la fuga es suficiente para diluir el metano y eliminar la propagación. La

mayoría de las fugas de metano que observamos son descargas de metano de agujeros pequeños. Como resultado, requerimos que los operadores usen detectores de gas y monitores si están dentro de un radio de 100 pies (30.5 metros). Lo mismo se aplica a la señalización en las granjas. El estándar de NRCS requiere que las antorchas estén a un mínimo de 50 pies (15 metros) de la fuente. Una distancia de 100 pies (30.5 metros) es una figura conservadora. Es importante usar dispositivos de monitoreo y colocar señalización sobre los riesgos en las granjas para reducir el riesgo de incendio. Las señales deben colocarse en la entrada de la granja, cerca de las instalaciones, y cerca del digestor.

¿Qué tan cerca puede estar una residencia de un digestor sin que haya preocupaciones de seguridad?

Desde una perspectiva regulatoria, la Ley de Ubicación de Granjas Porcinas se aplica a los digestores. En ella, los digestores, al igual que los establos o las lagunas, deben estar al menos a 1,500 pies (457 metros) de las residencias que no sean del propietario de la granja. Para un agricultor porcino que posee una casa en la granja, aunque esté exento de este requisito regulatorio, se recomienda usar esta distancia razonable como una guía para garantizar la seguridad de las personas y las propiedades.

Para obtener información adicional, visite nuestra página web.

UHF-RFID for Counting Weaned Pigs

Rachel Hodges, Suzanne Leonard

Accurate pig counting is crucial in livestock management to maintain pig inventories, track movements and site productivity rates, and optimize production systems. Manual counting can be error-prone and time-consuming, making automated technology solutions an attractive alternative. Commercially available camera systems for counting pigs advertise high accuracies of 99.9% or greater. However, this study investigated using an ultra-high frequency radio frequency identification system (UHF-RFID) as an alternative method for counting pigs. Utilizing UHF-RFID could require less hardware and enable individual pig identification, in addition to counting the number of pigs. Specifically, our goals were to (1) assess the effectiveness of an off-the-shelf UHF-RFID system and explore configurations to optimize its accuracy, and (2) evaluate the system's accuracy for counting nursery pigs moving along a hallway.

Preliminary Laboratory Testing

This study used commercially available UHF-RFID readers (Model #216030, GAO RFID Inc. Toronto, Canada) and button-type ear tags (Model #116330, GAO RFID Inc. Toronto, Canada). Preliminary laboratory tests evaluated four reader positions to determine the most reliable configurations to be used for field testing. The first position tested was the reader centered at a height of 0.25 m and facing perpendicular to the floor (Low; Figure 1). The Low position was used to determine how well the reader performed at the anticipated height of the pigs. The second position tested was the reader centered at a height of 0.64 m and facing perpendicular to the floor (Mid-Perp). Oriented in the same manner as the Low position, the Mid-Perp position was selected to determine how a greater reader height impacted detection rates. The third position evaluated was the reader centered at a height of 0.64 m and at a 30° downward angle (Mid-Angle). The fourth position tested was the reader centered at a height of 0.91 m and at a 30° downward angle (High-Angle). The Mid-Angle and High-Angle positions were used to evaluate if orienting the reader's face towards the pigs influenced detection rates, and if height was a limiting factor with these positions.

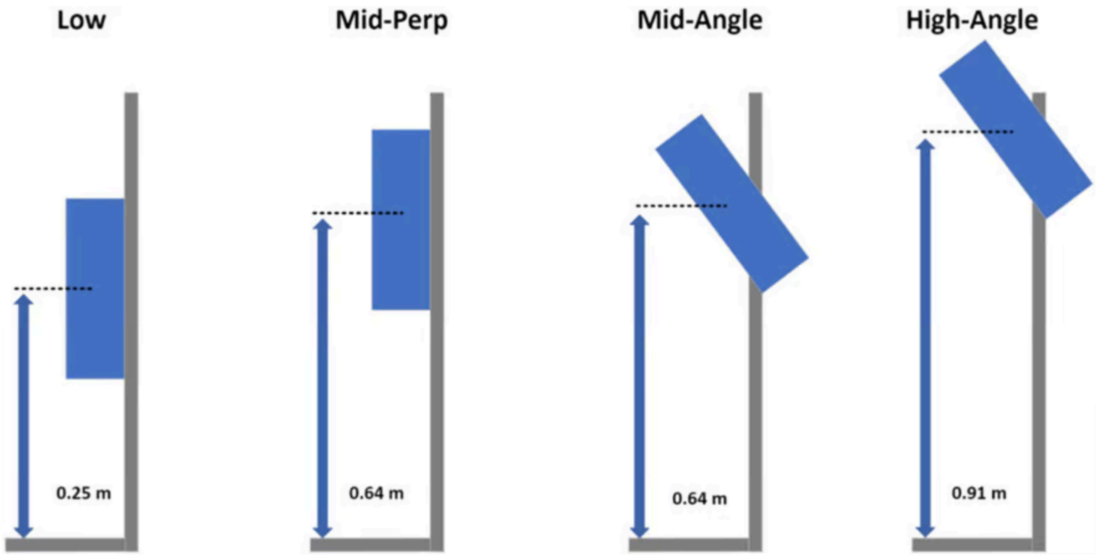

Figure 1. Illustration of the RFID reader (illustrated by blue rectangle) positions that were tested in the controlled laboratory environment, highlighting the distance from the ground to the center of the reader.

All four positions were evaluated at two read power levels (15 and 25, with 25 being the system's maximum setting) to determine optimal tag detection. To evaluate maximum tag read detection distance, an RFID tag was placed 2.03 m directly in front of the reader at a height of approximately 0.31 m and slowly moved forward towards the reader. Tags were moved closer until the reader was able to detect the tag and this distance was recorded. The process was repeated five times for each tag and a total of five randomly selected tags were used. Testing was repeated for each configuration and read power combination.

Results of the preliminary testing showed that the Low, Mid-Perpendicular, and Mid-Angle positions performed similarly, with average detection distances exceeding the hallway width (89 cm) at a read power of 25 (Figure 2). In contrast, the High-Angle position showed significantly lower detection accuracy and therefore was not used for field testing. The maximum read power (25) was chosen for field testing, as it provided the greatest detection distances.

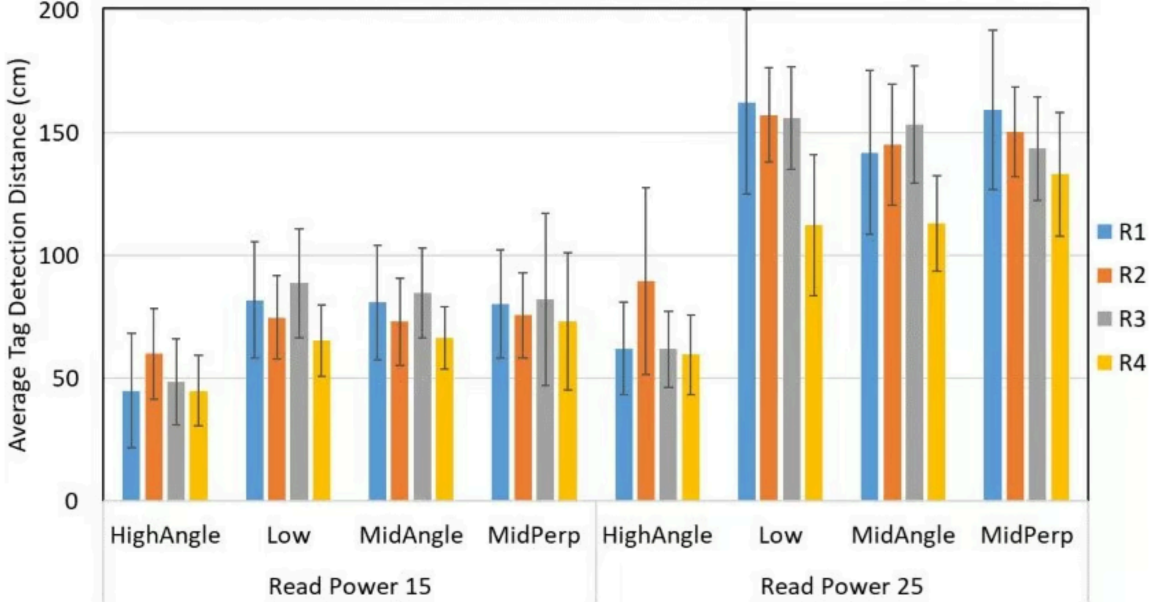

Figure 2. Four UHF-RFID readers were evaluated at four settings (HighAngle, Low, MidAngle, and MidPerp) and two read power settings (15 and 25) to determine the optimum configurations for field testing.

Field Testing

Field tests were conducted in a nursery barn with 39 weaned pigs, grouped by body weight into three groups of ten pigs and one group of nine pigs. Three RFID readers were installed along one side of a hallway with solid concrete flooring and metal gating on both sides (Figure 3). Pigs were identified with RFID tags in their right ears. Each group of pigs was walked along the length of the hallway a total of 10 times for each of the three reader positions, with five passes to the left and five passes to the right. The same caretaker walked the pigs for all passes using a single sorting panel. After each pass the pigs were held at the end of the hallway, regrouped, then released together to walk the other direction down the hallway.

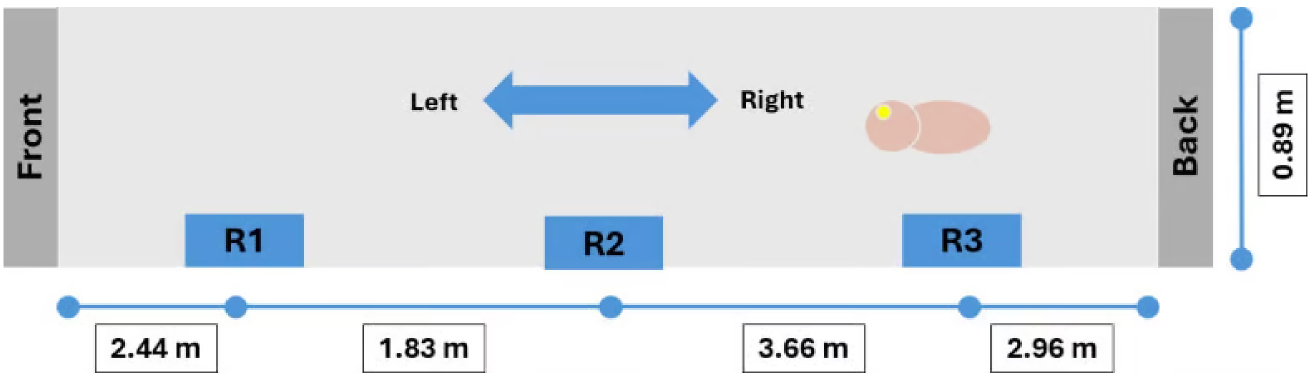

Figure 3. Three UHF-RFID readers (R1, R2, R3) were mounted on the side of the hallway. Groups of pigs were walked left and right in front of the readers.

Results revealed significant variation in detection accuracy based on reader location and position (Table 1). The middle reader (R2) in the Mid-Angle position achieved the highest detection rate (78.0%), whereas readers placed at hallway ends had consistently lower detection rates. Placement in the hallway center allowed pigs to move freely with less crowding, likely reducing tag obstructions from other pigs, thus improving detection.

Accuracy was generally greater when the tagged ear was closer to the reader (right-side passes).

Table 1. Mean (average) tag detection percentages and standard error (SE) for each RFID reader and position.

		Overall		Left		Right	
Reader	Position	Mean Percentage	SE	Mean Percentage	SE	Mean Percentage	SE
R1	Low	40.0	6.6	43.6	4.1	36.4	4.0
	Mid-Perp	37.4	8.6	50.3	4.9	24.6	5.5
	Mid-Angle	29.2	5.1	34.4	3.8	24.1	3.2
R2	Low	74.6	5.6	64.6	3.6	84.6	3.4
	Mid-Perp	70.3	8.2	75.4	4.7	65.1	4.6
	Mid-Angle	78.0	7.1	75.4	4.2	80.5	4.2
R3	Low	52.1	8.1	44.1	5.0	60.0	4.8
	Mid-Perp	27.7	7.1	27.7	3.9	27.7	4.4
	Mid-Angle	37.2	6.4	32.3	4.3	42.1	4.0

Conclusions

This study demonstrated the potential of UHF-RFID systems as a cost-effective, automated solution for pig counting. While the system achieved promising results under controlled laboratory conditions, its accuracy in field testing was below acceptable thresholds for usage in production systems. The off-the-shelf UHF-RFID system demonstrated several advantages over computer vision-based counting systems, including resistance to dust and lighting variations, portability, and individual pig identification. However, the 78% detection accuracy fell short of the advertised accuracy of camera-based pig counting systems. The additional material and labor cost of tagging each pig and potential for lost ear tags should be considered as well. Accuracy of the RFID system could be further improved by using multiple readers in sequence, tagging both ears of the pig, and optimizing reader angles for specific farm settings, although these additional steps may not be practical for some production systems and markets. Adjusting reader height for different pig sizes and encouraging single-file pig movement may also improve accuracy. With further refinement, UHF-RFID technology could provide swine producers with a practical and efficient alternative to manual counting.

For additional details, refer to the full research article.

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