NPB FINAL RESEARCH GRANT REPORT FORMAT

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Refining sample size recommendations for PQA Plus and CSIA audit tool #PR-005286

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5/30/2025

Industry Summary: The objective of this study was to compare and contrast differences in the occurrence of animal-based measures when using the Common Swine Industry Audit (CSIA) sampling method to the total farm inventory (observing all pigs). Pigs were evaluated across 60 farms between October 2022 and July 2023. Ten animal-based measures were assessed per pig, and the total occurrence of each measure was calculated for the total farm inventory (TOTAL). Utilizing farm maps and the same dataset, the CSIA sampling method was then calculated to randomly assess a subpopulation of pigs on farm by location as described in the audit (CSIA). The CSIA occurrences were then compared to TOTAL occurrences. On sow farms, total occurrences of body condition score of 1, severe lameness (non–weight-bearing), abscesses, open wounds, severe scratches (> 25% of the body), prolapses, vulva lesions, and shoulder sores occurred less for the CSIA sampling method compared to TOTAL. On the Nursery farms, occurrences of severe lameness, abscesses, open wounds, and hernias were less for the CSIA method compared to TOTAL. Lastly, on finisher sites, the occurrences of severe lameness, abscesses, open wounds, tail bites, prolapses, and vulva lesions were less for the CSIA method compared to TOTAL. In conclusion, these findings suggest that the sampling method currently used in the CSIA tool does not necessarily accurately estimate the occurrence of animal-based measures at the farm level. Furthermore, future work on swine farms should explore alternative sampling methods that more closely represent welfare conditions to that of the total farm inventory.

Key Findings:

- Animal welfare assessments and audits using sampling strategies to evaluate a subpopulation of pigs
- Sampling methods should accurately estimate the occurrence of animal welfare issues on a farm
- The CSIA sampling method found less animal based measure on-farm
- Future work is needed to find an effective sampling method to assess welfare

Keywords: swine, CSIA, PQA Plus, animal welfare, animal-based, assessment

Scientific Abstract: The objective of this observational study was to compare and contrast the occurrences of animal-based measures evaluated in the Common Swine Industry Audit (CSIA) with the use of 2 sampling methods (total farm inventory [TOTAL] vs the CSIA sampling method). Approximately 240,000 pigs were evaluated across 60 farms between October 2022 and July 2023. A map was created for each farm to identify individual pig location by pen/stall, room, and barn. Ten animal-based measures were assessed per pig, and the total occurrence of each measure was calculated (TOTAL). Utilizing farm maps and the same dataset, the CSIA sampling method was calculated to randomly assess a previously designated sample number of pigs per farm by location. The CSIA occurrences were then compared to TOTAL occurrences Total occurrences of body condition score of 1, severe lameness (non–weight-bearing), abscesses, open wounds, severe scratches (> 25% of the body),

prolapses, vulva lesions, and shoulder sores on sow farms were less for the CSIA method compared to TOTAL. On the Nursery farms, occurrences of severe lameness, abscesses, open wounds, and hernias were less for the CSIA method compared to TOTAL. Lastly, on finisher sites, the occurrences of severe lameness, abscesses, open wounds, tail bites, prolapses, and vulva lesions were less for the CSIA method compared to TOTAL. In conclusion, these findings suggest that the sampling method currently used in the CSIA tool does not necessarily accurately estimate the occurrence of animal-based measures at the farm level. Furthermore, future work on swine farms should explore alternative sampling methods that more closely represent welfare conditions to that of the total farm inventory.

Introduction: In contrast to a legislative approach, animal welfare regulations in the US are primarily driven by consumers requesting greater transparency regarding how their food is produced. Consumers have increased pressure on retailers to source their products from farms that adhere to specific animal welfare standards and expectations[3-5]. This consumer demand has in turn prompted animal agricultural shareholders to adopt assessment and third-party auditing procedures that ensure animal welfare standards are being met across the entire food supply chain[6].

Historically, on-farm assessment and third-party auditing programs have been composed of three categorical measures (a) environmental conditions (resource-based measures), (b) protocols, training, and standard operating procedures (management-based measures) and (c) behavioral and physiological responses from the animal (animal-based measures). Resource-based measures that assess the environmental conditions in which the animal lives (e.g., space allocation, flooring type, lighting schedules and pen design), and management-based measures that verify the implementation of the training and written protocols established for the farm, serve as indirect indicators of animal welfare[7]. Animal-based measures (e.g. body condition and severe lameness scoring) serve as direct indicators of welfare given such indicators measure the individual animal's response to their surrounding environment[6]. Most assessment and auditing programs include all three measures within the audit tool with greater weighting placed on animal-based measures to assess welfare quality on an individual and herd level[8].

The Common Swine Industry Audit® (CSIA)[9], developed in 2013, is a nationally recognized swine audit program that assesses animal welfare and pre-harvest food safety, and is part of an ongoing program following decades of work[10]. The CSIA is currently used as the primary verification tool for assuring that swine welfare standards are being met on-farm[4] and parallels expectations and standards outlined in the most utilized voluntary assessment program in the US swine industry to date, the Pork Quality Assurance Plus® (PQA Plus)[11]. The CSIA and PQA Plus® program are composed of 27 key topics, with animal-based measures accounting for most of the audit (35 questions), representing 55% of the total points[9]. Criteria and definitions of the animal-based measures are described in Table S1.

As stated in the CSIA, "All pigs need to be observed during the audit, but the benchmarking criteria are only calculated from a statistical sample of pigs… The sample size must be large enough to allow for detection of at least 1% occurrence at a 95% confidence level."[9] The sampling method utilized in the CSIA is based on work by Cannon and Roe[12], a method primarily applied for diagnostic testing and assessment of disease status within livestock populations. Taking this approach, the CSIA sampling method used to observe animal-based measures is based on two conditions: 1) Sampling size used ensures a 95% confidence that at least one animal within the sampling population is "positive" (i.e. diagnostic test is positive for disease presence, or, in this case, animal-based condition is identified in at least one animal) and 2) the occurrence of the disease/animal welfare condition within the population is assumed to be at 1%. This in turn results in farms with smaller populations (50 pigs or less) to have all pigs observed for animal-based measures and farms with larger populations to only observe animal-based measures from a "representative sample" of the farm as stated in the CSIA (Table S2). To the authors knowledge, there is no previous work describing the justification for using the 1% occurrence rate chosen for the CSIA sampling method and no previous work prior to this project has assessed the occurrence rate of each CSIA animal-based measure on commercial swine farms.

Objectives: The objective of this study was to validate swine population sampling size needed to accurately estimate animal benchmarking criteria.

Materials & Methods:

The authors worked with university officials within the Office of Institutional Animal Care and Use prior to initiating data collection on this project. The study was deemed an observational study, as no activities were conducted that had a physical or behavioral impact on the animals. Written confirmation was received and documented by the authors for purposes of the project. Animals were not owned by the university; therefore, any management or intervention strategies implemented for compromised animals observed during data collection were under the jurisdiction of the site veterinarian.

Farm type and selection

Twenty-eight US companies that held member positions on the CSIA Task Force were actively recruited to participate in the study via email. Two companies, one located in the Midwest and the other in the Southeast, agreed to participate and permit data collection on the farm. Data were collected across 4 production stage types (sow, nursery, wean to finish, and finish). For this study, a sow farm was defined as a facility that included breeding stock in a farrow-to-wean phase,[13] nursery farm was defined as an operation designed to house newly weaned pigs until they reached the grower stage,[14] wean-to finish farm was defined as a facility that raised young weaned pigs until they achieved market weight,[15] and finishing farm was a facility where pigs entered a finishing/feeding stage (around 9 to 11 weeks of age) and remained there until they achieved market weight.[13] Wean-to-finish and finisher farm data were compiled into 1 dataset labeled finishing. Companies provided access to farm data including comprehensive and up-to-date Excel (Microsoft Corp) files of actively managed farms by production type. For each file, farms were categorized by production type and allocated to 4 quartiles (< 499, 500 to 1,999, 2,000 to 4,999, and > 5,000) by farm size as an attempt to ensure an even selection distribution across smaller and larger farms. Each company enrolled 30 farms, with considerations given to biosecurity and on-farm labor needed to assist with data collection. A random number generator (Random.org) identified 20 sow farms, 10 nurseries, and 30 finisher farms across the 2 companies (Midwest company, n = 30: 10 sow farms and 20 finisher farms; Southeastern US company, 30: 10 sow farms, 10 nurseries, and 10 finisher farms). Prior to data collection, all farms were assigned an identification number by farm type. Farm data included total current inventory, total barn, room and pen number, and mean number of pigs per pen. Once information was collected, researchers worked directly with farm staff and veterinarians to schedule audits based on the company's biosecurity protocols and geographic location.

Animal-based measure data collection

Between October 2022 and July 2023, all CSIA/ PQA Plus animal-based measures (Supplementary Table S1) were collected on the total inventory (i.e., all pigs on the farm at the time of the audit) for each farm by Professional Animal Auditor Certification Organization–certified trained auditors.[16]

Sampling method

Two sampling methods were utilized: (1) Total inventory method: all animal-based measures for all pigs on the farm were recorded. A map was created for each farm to identify individual pig location by pen/stall, room, and barn. Ten animal-based measures were recorded as either a 1 (present) or 0 (absent) and included the pig location by pen, room, and barn. Empty stalls and pens were marked as empty and animals located in hospital pens were omitted from the dataset, as CSIA sampling methodology does not include any empty stalls/pens or hospital pens in the sampling selection. (2) The CSIA sampling method: utilizing farm maps and TOTAL inventory data, the CSIA was calculated on the same day with the use of a previously developed calculation tool by the National Pork Board.17 The calculation included the following 5 steps. Step 1: Quantify the population of pigs and production stage to be assessed, including breeding (e.g., sexually mature gilts, sows, boars, and neonatal piglets) and/or nonbreeding pigs (e.g., nursery pigs, grower pigs, gilts in a gilt development unit/isolation, and finisher-sized pigs). Step 2: Determine the minimum number of pigs to be observed per production phase based on the statistical sample outlined in the CSIA tool (Supplementary Table S2). Step 3: Calculate the percentage of pigs present by housing type (pens or stalls). Step 4: Determine the proportion of pigs by housing type to be observed to reach the designated sample size while ensuring the sample is representative across all housing types for the site. Step 5: Determine in which stalls and pens observations will be conducted before entering the barn, considering that all rooms and barns should be included in the sample size observed.

For pigs housed in groups, the number of pigs to be observed is divided by the mean number of pigs per pen to determine how many pens should be observed. The number of pens should always be rounded up (e.g., 5.4 pens require 6 pens to be observed). To select pigs housed in stalls, the following formula is used: every Xth stall = total number stalls / minimum number to evaluate. Empty stalls/pens and hospital pens were not included in the sampling calculation.

Statistical analysis

Data was analyzed with standard software (RStudio, version 4.1.0; The R Project for Statistical Computing). A Mann-Whitney U test18 was conducted to compare the occurrence of each animal-based measure per farm between the sampling methods (TOTAL vs CSIA). A nonparametric test was used because none of the animal-based measures had a normal distribution according to the Cramer–von Mises test.19 Statistical significance was declared at $P \leq .05$.

Results

A total of 239,709 pigs from 60 commercial farms were included in the dataset. Sow farm data were collected at facilities that included breeding stock (gilts, multiparity sows, boars) and preweaned piglets. The mean occurrences of a body condition score of 1 (BCS 1), severe lameness, abscesses, open wounds, severe scratches, prolapses, vulva lesions, and shoulder sores were less when the CSIA

sampling method was used in comparison with the mean occurrence of the TOTAL sampling method ($P \leq .01$). Tail bite occurrence was not different between sampling methods ($P > .05$; Table 1).

Nursery farm data were collected at facilities with recently weaned to grower pigs housed for approximately 6 to 8 weeks at the site. The mean occurrences of severe lameness, abscesses, open wounds, and hernias were less in nurseries when the CSIA sampling method was used in comparison with the TOTAL sampling method ($P \leq .02$). A BCS 1, severe scratches, and tail bite occurrences were not different.

Finishing farm data were compiled and included wean-to-finish and finisher farms. Wean-to-finish farms included facilities that raised recently weaned pigs until they achieved market weight and finisher farms included facilities housing nursery pigs (approx. 12 weeks of age) that remained in the facility until they achieved market weight. The mean occurrences of severe lameness, abscesses, open wounds, tail bites, prolapses, and vulva lesions were less in finishing farms when the CSIA sampling method was used in comparison with the TOTAL sampling method ($P \leq .02$). Severe scratches did not

Table 1—Animal-based measure mean, minimum, and maximum occurrences on sow farms with 2 sampling methods (Common Swine Industry Audit sampling method [CSIA] and total inventory sampling method [TOTAL]).

	CSIA		TOTAL		
Animal-based measure	**Mean ± SD (%)**	**Minimum–maximum (%)**	**Mean ± SD (%)**	**Minimum–maximum (%)**	***P* value**
BCS 1	0.04 ± 0.1	0–0.3	0.1 ± 0.2	0–0.6	< .02
Severe lameness	0.02 ± 0.1	0–0.2	0.12 ± 0.1	0–0.4	< .001
Abscesses	0.1 ± 0.1	0–0.6	0.7 ± 0.4	0.1–1.6	< .001
Open wounds	0.2 ± 0.3	0–0.9	1.7 ± 1.2	0.2–4.4	< .001
Severe scratches	0.1 ± 0.1	0–0.3	0.4 ± 0.7	0–2.9	< .01
Tail bites	0.0 ± 0.0	0–0.1	0.01 ± 0.04	0–0.2	> .99
Hernias	NA	NA	NA	NA	NA
Prolapses	0.0 ± 0.0	0–0.04	0.04 ± 0.1	0.0–0.2	< .001
Vulva lesions	0.1 ± 0.1	0–0.5	0.7 ± 0.6	0.0–2.4	< .001
Shoulder sores	0.2 ± 0.3	0–0.9	1.6 ± 1.3	0.03–4.7	< .001

A total of 238,709 pigs from 60 commercial farms were included in this study. Animal-based measures were collected between October 2022 and July 2023 on pigs housed on sow (n = 20), nursery (10), and grow-finish sites (30). Pigs enrolled in the study included breeding stock (gilts, multiparity sows, boars), preweaned piglets, nursery pigs, and grow-finish pigs. BCS 1 = Body condition score of 1. NA = Not applicable.

Table 2—Animal-based measure mean, minimum, and maximum occurrences on nursery farms with 2 sampling methods (CSIA and TOTAL).

Animal-based measure	CSIA		TOTAL		
	Mean ± SD (%)	Minimum–maximum (%)	Mean ± SD (%)	Minimum–maximum (%)	*P* value
BCS 1	0.01 ± 0.01	0–0.04	0.03 ± 0.1	0–0.2	< .5
Severe lameness	0.0 ± 0.0	0–0.0	0.03 ± 0.03	0–0.1	< .01
Abscesses	0.0 ± 0.01	0–0.04	0.09 ± 0.1	0–0.4	< .02
Open wounds	0.13 ± 0.2	0–0.04	1.1 ± 1.1	0.2–3.7	< .01
Severe scratches	0.0 ± 0.0	0–0.0	0.0 ± 0.01	0–0.02	< .5
Tail bites	0.0 ± 0.0	0–0.0	0.01 ± 0.03	0–0.1	< .2
Hernias	0.0 ± 0.0	0–0.0	0.1 ± 0.1	0–0.3	< .01
Prolapses	NA	NA	NA	NA	NA
Vulva lesions	NA	NA	NA	NA	NA
Shoulder sores	NA	NA	NA	NA	NA

Table 3—Animal-based measure mean, minimum, and maximum occurrences on finishing farms with 2 sampling methods (CSIA and TOTAL).

Animal-based measure	CSIA		TOTAL		
	Mean ± SD (%)	Minimum–maximum (%)	Mean ± SD (%)	Minimum–maximum (%)	*P* value
BCS 1	0.0 ± 0.0	0–0.02	0.0 ± 0.01	0–0.05	< .1
Severe lameness	0.01 ± 0.03	0–0.2	0.1 ± 0.1	0–0.4	< .001
Abscesses	0.07 ± 0.2	0–0.9	0.3 ± 0.4	0–2.1	< .001
Open wounds	0.2 ± 0.3	0–0.9	1.4 ± 1.8	0–8.9	< .001
Severe scratches	0.01 ± 0.1	0–0.2	0.02 ± 0.1	0–0.2	< .3
Tail bites	0.06 ± 0.2	0–0.9	0.32 ± 0.9	0–5.0	< .02
Hernias	0.1 ± 0.2	0–0.9	0.7 ± 0.6	0–2.4	< .001
Prolapses	0.0 ± 0.0	0–0.0	0.01 ± 0.04	0–0.2	< .03
Vulva lesions	0.0 ± 0.0	0–0.0	0.01 ± 0.04	0–0.2	< .03
Shoulder sores	NA	NA	NA	NA	NA

Discussion:

Pig welfare assessment and audits should be based on accurate and feasible indicators that reflect the animal's state in the context of the housing and management system. The CSIA is a nationally recognized auditing program specific to the US swine industry[4]. Although this audit has been extensively used commercially, there are no available analyses regarding the mean occurrences of animal-based measures present on commercial farms and how the CSIA audit tool captures such occurrences using a "representative sampling" method. Therefore, the objective of this observational study was to compare and contrast the occurrences of animal-based measure evaluated in the Common Swine Industry Audit using two sampling methods (TOTAL farm inventory vs CSIA sampling method).

Overall, the CSIA sampling method generated mean occurrences that were different from the total farm inventory for the majority (57-89%) of all animal-based measures across production stages. When comparing mean occurrence data in this study to previous work conducted in Europe, similarly low occurrence rates have been found across different animal-based measures. A study in the UK20 reported occurrence rates of severe lameness, tail lesions and severe scratches from over 1000 finisher farms at 0.2%, 0.1% and 0.3%, respectively. In addition, work conducted by Temple and colleagues[21] reported between 0 and 0.2% occurrence of five animal-based measures (body condition, tail bites, severe lameness, hernias and prolapses) across 30 finisher farms assessed with the Welfare Quality® program[22]. These low occurrence rates are in agreement with the results from our study and suggest these animal-based conditions impact a very small percentage of pigs on-farm and further investigation needs to be done to determine if the objective of the audit is to be able to detect such low frequently occurring animal-based measures on-farm.

When assessing mean occurrence across all production stages, shoulder sores on sow farms and open wounds across all production stages were the only measures that exceeded a 1% occurrence for the entire data set. Given the CSIA sampling method is based on the assumption that the condition has a 1% occurrence, consideration needs to be taken into account if the sampling method utilized currently in the CSIA audit tool is sufficient enough to detect such low occurring conditions. For example, the mean occurrence of hernias on nursery farms using the total farm inventory was 0.1%. If we apply this mean occurrence to the Cannon and Roe

methodology[12], a nursery site with 3000 pigs would need to observe 1895 pigs to achieve 95% confidence that at least one animal within the sampling population is identified with a hernia. This sampling method is drastically different from the current CSIA sampling method, which would require only 284 pigs to be observed. This difference reiterates the challenge of using such a sampling method such as Cannon and Roe12 given the purpose of the CSIA is not to detect one single animal but to determine the occurrence of animal-based measures by farm.

In addition, the reliance on the assumption of the 1% incidence rate for the CSIA is also a significant challenge given no studies or work have been conducted to rigorously evaluate the relevance of this incidence rate across any animal-based measures. The data collected in this study can serve as a first step in documenting animal-based measure occurrence rates in two large commercial systems in the US. Future work should include expanding the database to include more farms across different companies, regions, and production systems to validate true incidence rate of animal-based measures across swine farms.

The CSIA is also one of the few audits that provide a numerical scoring system to quantify compliance according to benchmarks of acceptability. The CSIA benchmarks were established using limited industry data and producer and expert experiences4. If a producer achieves an animal-based measure occurrence under the benchmark (i.e., <1% BCS of 1), the producer will receive the full points. If the animal-based measure occurrence rate is above the benchmark, the producer receives 0 points. In this study, the underestimation of animal-based measures using the CSIA sampling method resulted in more points received per farm than if the total inventory was used. For example, when using the CSIA sampling method in the 20 sow farms evaluated in this study, all the sow farms would have received full audit points because the occurrence of open wounds in the CSIA "representative sample" was less than the 1% benchmark. However, when using the total inventory sampling method, 13 of the 20 sow farms would not have received audit points specific to the open wound category because the occurrence exceeded 1%. These results suggest that the current sampling method underestimates the true occurrence rate on-farm and falsely elevates audit score as points are not lost using the CSIA sampling method. Additional work must be conducted to determine what the ultimate impetus of the CSIA audit is for the US swine industry and how retailers and allied industry want to use audit scores to reward or penalize producers based on animal welfare status.

This study is not without its limitations and multiple steps should be taken for future data collection to help minimize bias and capture a more holistic viewpoint across all production systems. First, only two companies were enrolled in the study, representing the Midwest and Southeast region. By default, data was not collected in states outside of Virgina, North Carolina and Iowa, thus limiting data interpretation to these geographic regions. Although more than two thirds of total hog production occur in the Midwest, the study was not able to collect data in other regions, thus making it difficult to apply our findings to farms located in other regions like the Southwest or Northeast. In addition, enrolling in only two companies also limits the study given most farms would have been trained using similar protocols and management practices. Future studies should include more companies and a diverse set of production systems to take into account variation in farm size, region, production type and marketing strategy.

Lastly, this study did not take into account potential observer bias amongst trained auditors. Although the auditors had sufficient education and training experience to conduct the study, no steps were taken to assess intra and inter-observer reliability throughout the data collection period and future work should require reliability testing within and between observers collecting data.

This exploratory observation study may be used assist the US swine industry to determine the sampling methodology to be used to accurately estimate the occurrence of animal-based measures on-farm. It should be noted that although the CSIA sampling method is very similar to other nationally implemented audits on a global basis including the Welfare Quality program[22] and the Canadian Pig Care program23. Under or over-estimating animal-based occurrences is likely not a unique issue to the CSIA audit alone and further work is needed to holistically evaluate audit sampling methodologies across programs and countries. However, given only 60 farms were enrolled in the study, caution should be taken to extrapolate results across farms or audit tools. If the CSIA audit tool continues to utilize the Cannon and Roe sampling approach[12], mean occurrence data should be used to re-estimate the appropriate "representative sample". In addition, further work is needed to consider what this type of accuracy means to the general public and consumer, and how variation in the "representative sample" of the audit and the true farm inventory impact actual welfare on-farm. It is also critical to acknowledge the logistical factors that play a role in auditing farms to ensure a sampling method can meet the financial and labor resources available to schedule, conduct and complete audits at a national level. This study serves as a baseline for documenting the total occurrence of animal-based conditions on US swine farms and should be used as a tool to help refine and improve verification tools like the CSIA and PQA Plus® program to support the US swine industry's commitment to continuous improvement for animal welfare.