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The impact of hemoglobin concentration on farrowing duration in sows

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Abstract

Concerns have been raised about the prevalence of anemia in sows, yet our understanding of its consequences, particularly its impact on the farrowing process, remains limited. This study investigated the relationship between hemoglobin concentration (**HbC**) and farrowing duration in sows. A total of 101 sows (n = 16 parity 0, 15 parity 1, 24 parity 2, and 46 parity 3 sows) were monitored for blood HbC (Hemocue Hb 201 device) from the ear vein before farrowing (day 112 of gestation) and between 40 to 48 h after farrowing (day 2). Sows were categorized as anemic (HbC < 10 g/dL), or nonanemic (HbC ≥ 10 g/dL) based on their day 112 HbC (i.e., prefarrowing status). Surveillance cameras recorded the farrowing process for each sow, complemented by human observation. Farrowing duration was defined as the time elapsed between the first piglet born and the last piglet born. All piglets were individually weighed within 18 h of birth, and stillborn piglets were identified using a lung flotation test conducted within 1 h of birth. The correlation between sow HbC, farrowing duration, and stillborn piglets was assessed using the PROC CORR procedure in SAS. Additionally, the effect of HbC category on labor duration was tested using the PROC MIXED procedure, with total piglets born included as a covariate. Anemic sows had a prolonged farrowing (7.2 h ± 0.92 min, $P < 0.001$) compared to nonanemic sows (3.5 h ± 0.88 min), and negative correlation was observed between prefarrow HbC and farrowing duration ($r = -0.62$, $P < 0.001$). There was a weak correlation between farrowing duration and stillborn piglets ($r = 0.32$, $P = 0.01$). No correlation was observed between farrowing duration and total born ($r = 0.22$, $P = 0.11$). There was no difference in total born (16.41 ± 0.7 vs 16.3 ± 0.7) between anemic (< 10 g/dL) and nonanemic (≥10 g/dL) sows, respectively. Factors such as barn temperature on the day of parturition and feed intake the day prior did not influence the observed differences in labor duration between anemic and nonanemic sows. In conclusion, maintaining HbC above 10 g/dL appears beneficial for sows, as lower concentrations of HbC are associated with prolonged labor and increased removal rates. Blood HbC could serve as a valuable biomarker for identifying at-risk sows, thereby aiding in improving herd management and productivity.

Lay Summary

Limited understanding exists regarding the implications of anemia on sows. This study investigated the impact of anemia, characterized by low hemoglobin concentration (**HbC**), on the farrowing process in sows. Anemic sows experienced farrowing duration twice as long as nonanemic sows, which was not explained by differences in litter size or feed intake before farrowing. This suggests that anemia in sows prior to farrowing may lead to adverse outcomes for both sows and piglets. Monitoring HbC before farrowing could help identify "at risk" sows, allowing for targeted interventions to improve herd management and productivity.

Key words: anemia, farrowing, hemoglobin concentration, sow

INTRODUCTION

Anemia, characterized by a deficiency in red blood cells or low blood hemoglobin concentration (**HbC**), serves as an indicator of nutritional deficiencies or underlying health issues, potentially affecting the health and reproductive performance of sows. Recent studies in sows reveal variable degrees of anemia at different stages of pregnancy or lactation (Castevens et al., 2020; McClellan et al., 2024). Castevens et al. (2020) reported that approximately 50% of 2,683 sampled sows were deemed anemic (<10 g/dL HbC), with a higher prevalence in older parity sows and in lactation, regardless of parity. McClellan et al. (2024) conducted a longitudinal study tracking HbC in the same sows over multiple reproductive cycles. Their findings revealed the highest prevalence of sow anemia at day 90 of gestation compared to earlier gestational timepoints (i.e., days 30 and 60), with an increasing prevalence during lactation across all parities. Furthermore, the recovery to optimal HbC after lactation showed a decline, particularly evident by parity 3. However, despite the observed prevalence, the specific consequences of anemia on sows remain largely underexplored in the existing literature.

Early human epidemiology studies linked anemia to dystrophic dystocia or prolonged labor (Traylor and Torpin, 1951; Zilliacus and Putkinen, 1952). Farrowing is an energy-demanding activity for the modern hyper-prolific sow (Feyera et al., 2018); thus, sows experiencing anemia may encounter challenges in providing optimal oxygen to tissues and organs, leading to reduced oxygen transport to uterine muscles and increased fatigue. The physiological stress associated with anemia could contribute to prolonged farrowing durations in sows, hindering the smooth progression of parturition.

Increased farrowing duration has been associated with a greater number of stillbirths (Oliviero et al., 2010; Feyera et al., 2018), likely due to the prolonged farrowing

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process causing hypoxia in piglets. Additionally, prolonged farrowing durations can expose sows to additional stress, impacting postpartum recovery, adverse development of the microbiota (Hasan et al., 2018) and fertility issues (Oliviero et al., 2013).

Considering the potential implications of anemia on the farrowing process, this study investigated the relationship between HbC in sows and the duration of farrowing, with a particular focus on understanding the potential implications of anemia on the farrowing process. By examining how prefarrowing HbC may correlate with farrowing duration, as well as assessing reproductive outcomes, this research aims to contribute to the development of proactive measures aimed at mitigating the risks associated with anemia during farrowing, thereby optimizing sow welfare and productivity outcomes in commercial swine operation.

MATERIALS AND METHODS

This study was approved by the Institutional Animal Care and Use Committee at the South Dakota State University and Use Committee (IACUC # 2209-051). The experiment was conducted in the sow barn at the South Dakota State University Swine Education and Research Facility in Brookings, SD 57006, USA.

Animals, Housing, and General Management

A total of 101 females, distributed among 5 farrowing groups of 16 to 23 sows each, were utilized in this study, ranging from parity 0 (gilts) to parity 3 sows (n = 16, 15, 24, and 46 for parity 0, 1, 2, and 3, respectively). The sows and gilts were housed in gestation stalls (0.61 m × 1.98 m) from breeding/weaning until pregnancy confirmation at 28 to 30 d after breeding, then moved to group housing at 19 to 25 sows/pen (8.53 × 8.20 m^2/sow). Around day 110 of gestation, females were transferred to farrowing crates (1.83 m × 2.43 m). The average daily minimum to maximum temperatures inside the barn during the experimental period was recorded for each farrowing group.

Gestation and Lactation Diets

All females were provided gestation and lactation diets formulated to meet or exceed nutrient requirement estimates for pregnant and lactating gilts based on the expected litter size of 14 piglets (NRC, 2012). Iron content across both phases was 3-fold greater than the estimated iron requirements based on estimated sow intakes. In gestation, females were fed once per day at approximately 2.0 to 2.2 kg of feed per sow to maintain a body condition score of 2.5 to 3. Electronic sow feeders (Gestal 3G, Jyga Technologies Inc., Saint-Lambert-deLauzon, QC, Canada) were used to provide daily feed allotment when housed in gestation pens. Upon moving into the farrowing room, sows were provided the lactation diet using an electronic feeding system (Gestal Solo, Jyga Technologies Inc.). The daily feed allotment was maintained at 2.7 to 2.9 kg/d per sow from the time of transfer until farrowing, dispensed in six meals per d, in three-hour increments from 5:00 a.m. to 8:00 p.m. The meals that were called for or not called for by each sow were recorded, and estimated feed intake was derived from these records. Once sows began farrowing, the feeding amount for each sow was followed by a step-up program according to the standard barn feed curve by parity to achieve "ad libitum" intake within 5d after farrowing.

Blood Collection and Hemoglobin Testing

Blood samples were collected from an ear vein of sows using a prick with 20 ga × 2.5 cm needle and loaded into disposable microcuvettes (HemoCue America, Brea, CA). Microcuvettes were analyzed using the HemoCue Hb 201 device (HemoCue America), with the resulting HbC displayed and recorded within 60 seconds. The HemoCue is a suitable indicator of blood HbC and was determined to be within 1% of laboratory analysis of HbC when comparing blood collected at the same location (i.e., arterial vein) (Kutter et al., 2020) and within 4% when comparing laboratory analysis of blood collected at a different location (i.e., ear vein vs jugular) (Maes et al., 2011). Sows were categorized as anemic using a threshold of <10 g/dL HbC (NRC, 2012; Bhattarai et al., 2019). Blood testing occurred at prefarrowing (day 112) to determine each sow's anemia status going into farrowing and again between 40 and 48 h (day 2) after farrowing was completed.

Farrowing Assistance Protocol and Data Recording

To monitor the farrowing process, surveillance cameras (Reolink, New Castle, DE) were employed, complemented by human observation (checked hourly by trained research technicians and barn staff). Sleeving, following barn protocol (using obstetrical sleeves and lubricant, ensuring not to touch crate surfaces with gloved hands prior to sleeving), was employed when 60 min had passed since the birth of the previous piglet. When sleeved by a research technician, if a piglet was felt in the birth canal, it was pulled. One piglet was attempted to be retrieved during each sleeve unless there was more than one pig in the birth canal at one time, in which case, both piglets were pulled. The research technician did not sleeve again until 60 min elapsed. Oxytocin was not administered during this experiment. Farrowing duration was defined as the interval of time elapsed between the birth of the first and last piglet of the litter. The actual birth time for each piglet was recorded. Identification of stillborn piglets was done using a lung flotation technique. Individual piglet weight and sex were recorded within 18 h after farrowing. All instances of sow removals were tracked from the point of farrowing through the subsequent reproductive cycle until the conclusion of their pregnancy and were categorized as "stayed" or "removed."

Statistical Analysis

To ensure the validity of our statistical approach, we performed checks for the assumptions of ANOVA, including homogeneity of variances and normal distribution. The association between sow HbC and farrowing duration was determined using a linear mixed model with the PROC MIXED procedure in SAS (ver. 9.4, SAS Institute Inc., Cary, NC, USA). The effect of sow HbC on farrowing duration was by analysis of variance with total born used as a covariate. Differences in main effects were tested using Tukey's honest significant difference tests. Correlation analysis was employed to analyze the correlation between sow HbC prefarrowing status and stillborn percentage. Stillborn percentages were calculated as the number of stillborn piglets divided by the total number of pigs born. Association of the risk factors HbC at day 112 of gestation and farrowing duration with sow removal was analyzed using Cox regression analysis. The time variable was defined as the day of removal, with removal occurring 140 d or less after initial

HbC sampling at day 112 of gestation. Sow longevity served as the censoring variable; a sow was considered censored if it remained in the herd throughout the study period. In this context, a longevity value of 0 indicated that a sow was censored, while a value of 1 indicated that the sow was removed within 140 days. Statistical significance was set at $P < 0.05$.

RESULTS

Reproductive Outcomes in Anemic vs Nonanemic Sows

Based on the day 112 gestation timepoint at which HbC was initially tested, 53 females were classified as anemic, while 48 were nonanemic going into farrowing (Table 1). Within the anemic group, 11 females were categorized as young parities (parities 0 and 1), and 39 were categorized as older parity females (parities 2 and 3); among the nonanemic group, 17 females were young parity and 31 were older parity females.

Hemoglobin concentration was lower ($P < 0.001$) in anemic sows at day 112 of gestation and at day 2 of lactation than in nonanemic sows (Table 1). In both anemic and nonanemic groups, HbC declined from day 112 of gestation to day 2 of lactation. Farrowing duration was greater ($P < 0.001$) in the anemic sow group than the nonanemic sow group, with no difference in total born between groups. Stillborn rates between anemic and nonanemic sows did not differ. There was no difference in piglet birth weight and total born litter weight between anemic and nonanemic sows. A weak negative correlation ($r = -0.20$; $P = 0.045$) was observed between sow HbC at day 112 of gestation and stillborn rates (Figure 1).

When examining the sow HbC data more precisely (Table 2), sows were categorized as 1, 2, 3, or 4 for HbC ranges of <9.0, 9.0 to 9.9, 10.0 to 10.9, and ≥11 HbC, respectively. Category 1 sows had a greater ($P = 0.001$) farrowing duration (750 min) than all other HbC categories, while category 2 sows had a greater farrowing duration (510 min) than category 3 (306 min) ($P < 0.001$) and 4 (246 min) ($P < 0.001$).

Anemia Prevalence by Parity and Farrowing Duration by Parity Category

The prevalence of anemia among sows entering farrowing on day 112 varied ($X^2 = < 0.001$) across parity categories (Figure 2). Anemia prevalence increased with advancing parity. Across parity categories, young anemic sows had greater farrowing duration (602 ± 64 min; $P < 0.001$) than young nonanemic sows (261 ± 58 min). Similarly, older anemic sows had greater farrowing duration (560 ± 31.1 min) than older nonanemic sows (296.6 ± 34.9 min; $P < 0.001$).

Feeding Time, Estimated Feed Intake, and Barn Temperature by Hemoglobin Status

The time elapsed since the last feeding and the estimated pre-farrow feed intake showed no differences between anemic and nonanemic sows (Table 3). Mean ± SD average temperature for each farrowing group was as follows: 21.7 ± 0.6, 20.3 ± 0.2, 19.0 ± 1.8, 20.4 ± 1.1, and 18.8 ± 0.4 °C for farrowing groups 1, 2, 3, 4, and 5, respectively. There were no differences in farrowing duration by group or in the interaction between group and sow HbC. Additionally, average, high, and low barn temperatures on the day of farrowing exhibited no differences between anemic and nonanemic sows across all groups.

Sow Removals by Hemoglobin Status and Farrowing Duration

Across the 101 sows enrolled in this study, 45.3% of sows entering farrowing in an anemic state were removed ($n = 24$) (Table 4), while in comparison, 14.6% of nonanemic sows were removed ($n = 7$). There was an association between sow HbC at day 112 of gestation and sow longevity within 140 d after initial HbC testing (day 112 of gestation) (Table 5). The risk of sow removal increased as sow HbC decreased

Table 1. Reproductive outcomes in anemic vs. nonanemic sows

Variable	Anemic (<10 g/dL HbC)	Nonanemic (≥10 g/dL HbC)	SEM	*P*-value
Number of sows, *n*	53	48	–	–
Younger parity females				
Parity 0, *n*	5	11	–	–
Parity 1, *n*	9	6	–	–
Older parity females				
Parity 2, *n*	10	14	–	–
Parity 3, *n*	29	17	–	–
Late gestational HbC, g/dL	9.5	11.1	0.15	<0.001
Early postpartum HbC, g/dL	9.0	9.7	0.22	<0.001
Farrowing duration, min	570.6	285.0	29.4	<0.001
Total born, n	16.8	16.6	0.72	0.813
Stillborn[a], %	8.0	5.0	1.0	0.162
Birth weight, kg	1.5	1.5	0.04	0.468
Litter weight, kg	22.9	22.5	1.07	0.627

[a]Stillborn percentage is expressed as a percentage of stillborn piglets relative to the total number of piglets born.

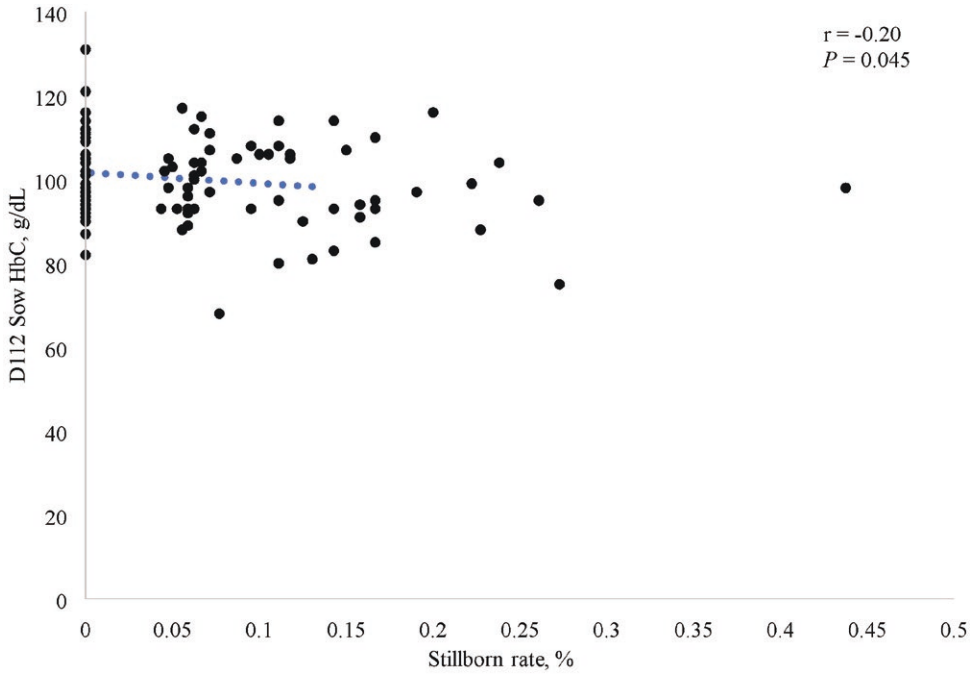

Figure 1. Correlation between sow HbC (g/dL) at day 112 of gestation and stillborn rates (%).

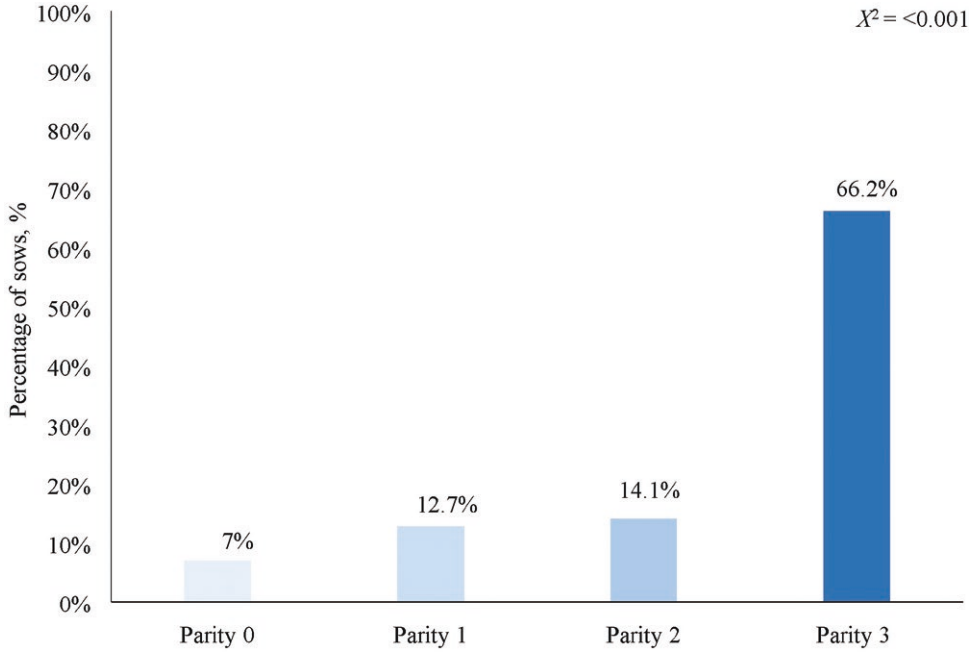

Figure 2. Prevalence of sows deemed anemic (<10 g/dL HbC) by parity at day 112 of gestation.

Table 2. Hemoglobin concentration category by farrowing duration

HbC category	1	2	3	4	SEM	*P*–value[a]
Range, g/dL	<9.0	9.0–9.9	10.0–10.9	≥11	–	–
Sows, *n*	13	40	29	19	–	–
Farrowing duration, min	750[a]	510[b]	306[c]	246[c]	54	<0.001

[a]Different superscripts a, b, c within the same row indicate differences at $P < 0.05$.

Table 3. Feeding time and prefarrowing feed intake for anemic vs. nonanemic sows

Variable	Anemic (< 10 g/dL HbC)	Nonanemic (≥10 g/dL HbC)	SEM	*P*-value
Time elapsed since last feeding[a], min	301.6	231.2	0.9	0.150
Prefarrowing feed intake, kg	3.2	2.9	0.3	0.525

[a]Feed drops occurred simultaneously for all sows six times a day, at 5:00 a.m., 8:00 a.m., 11:00 a.m., 2:00 p.m., 5:00 p.m., and 8:00 p.m., respectively. The total daily feed was distributed across these time periods, with the first two accounting for 20% each and the remaining four for 15% each. The maximum amount of feed distributed per meal was up to 4.84 kg. There was an additional 0.05 kg "stimulation" drop at the beginning of each new period. Sows were allowed to consume 20% more than their assigned parity curve.

Table 4. Sow removal reasons for anemic vs. nonanemic sows

Reason for removal	Anemic (< 10 g/dL HbC)	Nonanemic (≥10 g/dL HbC)
High stillborn rate	14	4
Negative pregnancy	4	3
Died; unknown	2	1
No heat	1	–
Died; farrowing difficulty	1	–
Uterine prolapse; euthanized	1	–
Joint infection; euthanized	1	–

Table 5. Results of survival analysis of the complete model for associations between sow longevity and sow HbC at day 112 of gestation and farrowing duration

Risk factor	Hazard ratio	SEM	*P*-value
Sow HbC	0.963	0.017	0.028
Farrowing duration	1.002	0.001	0.004

(HR: 0.963; SEM: 0.017; *P*-value: 0.028). This suggests that for every 1 unit decrease in HbC, the risk of removal increased by 3.7%. Additionally, the risk of sow removal increased as farrowing duration increased (HR: 1.00; SEM: 0.001; *P*-value: 0.004), indicating that for every 1-minute increase in farrowing duration, the risk of removal increased by 0.2%.

DISCUSSION

There is currently limited research on sow anemia and its potential implications on the farrowing process; this work provides compelling evidence of an important association between HbC and farrowing duration in sows. Anemic sows, characterized by <10 g/dL HbC, exhibited notably longer farrowing durations than their nonanemic counterparts.

Despite similar reproductive parameters such as total born, average piglet birth weight, and total born weight between anemic and nonanemic sow groups, anemic sows had a 2-fold greater duration of farrowing compared to nonanemic sows. This disparity in farrowing duration may stem from physiological changes associated with low HbC, including decreased muscle strength and uterine contractions, similar to what has been observed in anemic human subjects during labor (Malhotra et al., 2002). Our observation of a weak negative correlation between farrowing duration and stillborn rates aligns with previous research (Langendijk and Plush, 2019; Bosch et al., 2023; Schoos et al., 2023), linking stillborn rates to prolonged labor durations.

The prolonged farrowing may also heighten stress levels in the sow and may lead to an increased incidence of human assistance during the farrowing process. While this study used a 60-min delay between piglets to signal sleeving intervention (defined as manually assisting piglet delivery from the sow's birth canal), a 20 to 30-min delay is common industry practice. Thus, prolonged farrowing will increase the likely number of times a given sow is sleeved. While sleeving intervention is generally viewed positively, it may carry potential consequences such as a greater risk of introducing bacteria beyond the cervix, potentially leading to uterine infections and/or postfarrowing fever. This could provide a rationale for why we observed increased cull rates postfarrowing in anemic sows.

The survival analysis suggests a higher proportion of sow removals, including deaths or culls, among anemic sows compared to nonanemic sows, highlighting the potential broader consequences of maternal anemia on sow welfare and productivity. While sow removal from a herd may not depend on the biological factors of the sow alone, our Cox regression analysis demonstrated that lower HbC levels at day 112 of gestation are associated with an increased risk of sow removal, reinforcing the critical role of maternal health in ensuring sow stayability within the breeding herd. As HbC levels decline, the risk of removal increases, suggesting that proactive monitoring and management of anemia in pregnant sows may be essential for improving herd stability. Furthermore, considering an average of 300 min longer farrowing duration in prolonged farrowing sows (categories 3 and 4), that would represent a 60% greater risk of culling. The observed effect of increased farrowing durations on sow removal risk indicates that prolonged farrowing further compromises sow removal rates.

A possible limitation of our study was the disproportionate representation of parity 2 and 3 sows compared to parity 0 and 1 sow. Based on previous data, it is expected a greater percentage of anemic sows with higher parity (Normand et al., 2012; Castevens et al., 2020; Noblett et al., 2021; McClellan et al., 2024). However, the effect of HbC on farrowing duration in both young and old sow categories consistently revealed a negative impact of anemia on farrowing duration across all parity groups. Our data indicates that sows entering farrowing with an HbC of at least 10 g/dL farrowed quicker, regardless of parity.

While this study found that nonanemic sows had shorter farrowing durations compared to anemic sows, determining an "ideal" duration remains challenging. Recent commercial data suggests parturition typically lasts around 240 min but can vary widely, from 30 to 720 min, with an average litter size of 16 piglets (Gourley et al., 2020). In our study, farrowing durations ranged from 127 to 1413 min, with an

average litter size of 16 piglets. Notably, we did not administer oxytocin and allowed for a longer sleeving interval to accurately assess farrowing duration without compromising sow welfare or litter size.

A previous study with an average litter size of 12.7 ± 3 piglets suggested a threshold of 300 min to avoid an increased risk of hypoxia in piglets (Oliviero et al., 2010). There are limited farrowing observation studies done on sows producing large litters to help define what an adequate farrowing time looks like in sows farrowing 16 + piglets and whether the farrowing time threshold should remain under 300 min for large litters to help mitigate stillborn incidence and sow exhaustion. While the threshold of 300 min for farrowing duration was established based on smaller litter sizes, achieving a target of 300 min or less may still be possible with adequate support for sow physiological parameters, such as higher HbC observed in our study. We observed that sows falling above an HbC threshold of 10 g/dL were able to maintain a farrowing duration near 300 minutes or less and required minimal assistance.

CONCLUSIONS

Anemic sows, below the threshold of 10 g/dL HbC, experienced farrowing duration twice as long as nonanemic sows, which was not explained by differences in litter size or feed intake before farrowing. This suggests that anemia in sows prior to farrowing may lead to adverse outcomes for both sows and piglets. Monitoring sow HbC before farrowing could help identify "at risk" sows and allow for targeted interventions to improve herd management and productivity. Additionally, our findings indicate that lower HbC levels and increased farrowing durations are associated with an increased risk of sow removal, highlighting the importance of addressing maternal anemia to enhance sow welfare and reduce culling rates.

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Author Contributions

Katlyn McClellan (Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing—original draft, Writing—review & editing), Sydney Sheffield (Data curation), and Crystal Levesque (Conceptualization, Data curation, Investigation, Methodology, Resources, Supervision, Writing—review & editing)

Conflict of interest statement

None declared.

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