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SOW FARROWING WEIGHT, LITTER SIZE AND SEX RATIO AS CORRELATES OF EARLY HAEMOGLOBIN CONCENTRATION IN LARGE WHITE AND LANDRACE PIGLETS

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ABSTRACT

Early differences in neonatal haemoglobin concentration and packed cell volume can affect piglet vitality under intensive conditions. This observational longitudinal study examined associations between sow farrowing weight, litter size, and litter sex ratio and early haematological status in Large White and Landrace piglets. Ten recently farrowed sows (five of each breed) and their litters were monitored from birth to eight weeks of age at a commercial piggery in Niger State, Nigeria. Sow weight was estimated from heart-girth and body-length measurements. Litter size and the proportion of male piglets were recorded at farrowing. Blood samples were obtained from a sex-stratified subset of piglets on days 3–5 and at week 8. All piglets received a routine 200 mg iron-dextran injection on day 3. Because the principal explanatory variables are litter-level attributes, the ten litters were treated as the primary independent units; associations were explored by multiple linear regression and interpreted as exploratory. Higher sow farrowing weight and larger litter size were each associated with lower early haemoglobin concentration and packed cell volume. A higher proportion of male piglets showed a similar directional association. The combined model accounted for a substantial proportion of variation in early haemoglobin (R^2 = 0.833), although the small number of independent clusters limits precision. No associations remained detectable at week 8. The findings indicate that routinely recorded sow and litter characteristics are associated with early haematological status and may help identify litters that warrant closer monitoring under commercial intensive conditions.

Keywords: Haemoglobin concentration; Iron status; Litter sex ratio; Litter size; Sow weight

INTRODUCTION

The swine industry remains an important contributor to global food security and economic sustainability. Intensive pig production systems are increasingly relied upon to meet rising demand for affordable animal protein, particularly in tropical regions such as Nigeria, where commercial pig farming continues to expand. Among the constraints facing intensive pig production is the persistence of suboptimal early haematological status in neonatal piglets. This condition is predominantly linked to limited iron reserves at birth and the absence of access to environmental (soil) iron under intensive concrete-floor housing (Nguyen *et al*., 2019; Kiarie *et al*., 2023). Neonatal piglets are born with approximately 50 mg of iron stores, an amount insufficient to support their rapid early growth and expanding blood volume. Sow milk supplies only about 1 mg of iron per litre, far below the piglet's daily requirement of 7–16 mg (Amdi *et al*., 2020).

Low haemoglobin concentration and packed cell volume in the first days of life have been associated with reduced vitality, impaired growth performance and elevated pre-weaning morbidity (Egbe-Nwiyi *et al*., 2021). Although routine intramuscular iron supplementation (typically 200 mg iron dextran on day 3) is standard practice on commercial farms, early haematological status still varies. Understanding the maternal- and litter-level factors associated with this variation is therefore important for practical farm-level risk identification.

Sow weight at farrowing is a critical determinant of reproductive outcome. Sows with greater body weight often support larger litters. Yet, the associated metabolic demands during late gestation may constrain the distribution of maternal resources, including micronutrients such as iron, among individual foetuses (Krogh *et al*., 2021). Litter size exerts a related influence: larger litters increase competition for colostrum, milk, and functional teats, reducing per-piglet nutrient acquisition during the critical neonatal period (Schmitt *et al*., 2021; Pedersen *et al*., 2020; Starzyński *et al*., 2024). Litter sex ratio adds a further layer of complexity. Male piglets typically exhibit faster early lean-tissue accretion and may therefore impose higher metabolic and iron demands than female littermates (Mori *et al*., 2021).

Although each of these factors has been examined individually in temperate production systems, their joint associations with early haemoglobin concentration and packed cell volume under tropical intensive conditions remain incompletely quantified for the Large White and Landrace breeds that dominate commercial pig production in Nigeria. This observational study therefore evaluated sow farrowing weight, litter size, and litter sex ratio as correlates of early haematological status in intensively managed Large White and Landrace pigs. The work is

exploratory, given the limited number of independent litters, and is intended to identify routinely recorded farm-level indicators that may help flag litters for closer haematological monitoring rather than to establish a validated predictive model.

MATERIALS AND METHODS

Study Area

The study was carried out at Phinada Piggery, a commercial farm specialising in intensive production of Large White and Landrace pigs, located along Garam in Niger State, Nigeria (Latitude 9°20′56″ N, Longitude 7°18′54″ E). The area has a tropical climate, with average temperatures ranging from 20.6 °C to 33.3 °C and annual rainfall between 1 100 and 1 600 mm, distributed across distinct dry and wet seasons. All animal handling followed the National Code for the Care and Use of Animals for Research Purposes.

Study Design and Animals

An observational longitudinal study was conducted. Ten recently farrowed sows, comprising five Large White and five Landrace, were purposively selected from the resident herd with their litters, resulting in ten sow/litter units monitored continuously from birth to weaning at eight weeks of age (56 days). The eight-week weaning age reflected the farm's standard commercial practice. No experimental treatments or random allocation of treatments were involved; the design is therefore observational rather than experimental. Breed differences were examined through between-breed comparisons at the sow/litter level (n = 5 per breed) rather than as a regression term, because the small number of litters per breed could not support a stable combined model.

Management of Sows and Piglets

Sows were housed individually in farrowing pens of approximately 4.32 m² with concrete flooring and slatted dunging areas, under an all-in-all-out system with routine cleaning and disinfection. Sows were fed a standard commercial lactation diet twice daily, with quantity adjusted according to litter size, and clean water was provided ad libitum through nipple drinkers. Piglets remained with their dams throughout lactation. Navel disinfection was performed immediately after birth, and teeth were clipped within the first 48 hours. On the third day after farrowing, all piglets received a standard intramuscular injection of iron dextran providing 200 mg of iron per piglet as a routine preventive measure. Creep feed was introduced from the second week of life. Pre-weaning mortalities were recorded and remained within the range expected for commercial production.

Data Collection at Farrowing

Sow body weight at farrowing was estimated from heart-girth and body-length measurements taken with a flexible measuring tape. Weight was calculated using the widely applied agricultural-extension geometric formula: body weight (kg) ≈ (heart girth² × body length) × 69.3 when measurements are in metres (equivalent to the imperial form (girth² × length)/400 that yields weight in pounds). This approximation is commonly used on commercial farms when platform scales suitable for mature sows are unavailable and is subject to measurement error, typically ±3–10% depending on technique and body condition. Values are therefore treated as approximate rather than direct scale measurements. The number of functional teats was recorded by visual inspection with the sow standing. For each litter, we recorded the total number of piglets born alive and the litter sex ratio (percentage of male piglets) immediately after farrowing, before moving any piglets. Piglets were weighed within 24 hours of birth and weekly thereafter using calibrated spring dial scales. Rectal temperature was measured weekly with a digital thermometer.

Blood Collection and Haematological Analysis

Ten piglets per litter, stratified by sex (five males and five females where available), were randomly selected for blood sampling. Blood samples of three millilitres were collected from the marginal ear vein between 09:00 and 11:00 hours on days three to five after farrowing and again at week eight. Of each sample, 1 ml was placed in EDTA-coated tubes for haematological

analysis and 2 ml in plain tubes, which were allowed to clot and centrifuged to obtain serum for biochemical analysis. Packed cell volume was determined by the microhaematocrit method. EDTA blood was drawn into heparinised capillary tubes, sealed with clay, and centrifuged in a microhaematocrit centrifuge (LW Scientific or equivalent veterinary microhaematocrit model) operated at a fixed speed of 12 000 rpm (generating approximately 14 500–15 000 × g) for exactly 5 minutes. The packed red-cell column was read against a calibrated haematocrit reader card. Haemoglobin concentration was measured using a HemoCue Hb 201+ haemoglobinometer (HemoCue AB, Ängelholm, Sweden), a photometric point-of-care device that has been widely validated for use in piglets. The instrument was calibrated according to the manufacturer's instructions at the start of each analytical session using certified control solutions. Daily internal quality-control materials (low and normal levels) were run before sample analysis; results were accepted only when control values fell within the manufacturer's established acceptable ranges. Approximately 10 % of samples (selected systematically across litters and sampling days) were analysed in duplicate to assess analytical precision; the coefficient of variation between duplicates was maintained within laboratory acceptance limits (typically < 5 % for haemoglobin). A certified laboratory technologist at a veterinary clinic in Minna performed all

laboratory procedures, following standard clinical laboratory protocols. The first sampling window (days three to five) overlapped with the day-three iron injection, so some piglets had already received supplementation by the time of sampling; the early result is accordingly interpreted as reflecting haematological status around, rather than strictly before, iron administration. Where litters lost piglets to pre-weaning mortality before week eight, the second sample was drawn from the remaining cohort rather than the identical set of piglets, so the week-eight comparison is treated as cohort-level rather than strictly paired.

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Operational Definition of Haematological Status

A statistically lower haemoglobin concentration does not, by itself, establish clinical or iron-deficiency anaemia. Group mean values were therefore compared against published piglet-specific reference ranges for early neonatal life (haemoglobin 7.14–7.90 g/dL and packed cell volume 24.4–26.5 % at approximately day 1; Cincović *et al*., 2020). Against this reference, the mean early haemoglobin concentration in Large White piglets (6.64 g/dL) fell below the lower limit, consistent with anaemia at the group level. In contrast, the Landrace mean (7.64 g/dL) fell within range. Throughout this paper, “haemoglobin concentration”, “packed cell volume” and “early haematological status” describe the outcomes actually measured; the term “anaemia” is used only when a group mean falls below the cited reference.

Statistical Analysis

Data were analysed in SPSS version 27. Descriptive statistics (mean ± standard deviation) summarised sow, litter, and piglet characteristics, and independent-samples t-tests compared these between breeds at the sow/litter level (n = 5 per breed). Multiple linear regression was used to examine the independent and combined association of sow farrowing weight, litter size and litter sex ratio with piglet haemoglobin concentration and packed cell volume. The model was fitted to piglet-level observations pooled across litters (approximately 100 piglets nested within 10 litters). Because sow weight, litter size and sex ratio were each measured once per litter, the ten litters, not the individual piglets, are the true independent units for these predictors. Ordinary

least-squares estimates that ignore this clustering may understate standard errors and inflate apparent explanatory power; consequently, all regression results are presented as exploratory associations rather than confirmatory population estimates. Residual plots were examined for gross departures from linearity and homogeneity of variance. Variance-inflation factors (VIFs) for the three predictors were all < 2.0, indicating acceptable multicollinearity. The overall model for early haemoglobin concentration yielded $R^2 = 0.833$, adjusted $R^2 = 0.733$, $F(3, \approx 96) \approx 159.6$ (model $p < 0.001$). Approximate 95 % confidence intervals and t-statistics (t = B/SE) are supplied for each coefficient. A linear mixed-effects model with litter as a random intercept was considered but could not be estimated with adequate precision at n = 10 clusters. Statistical significance was assessed at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Sow, Litter and Piglet Characteristics

Sow farrowing weight, litter size and litter sex ratio did not differ significantly between breeds (Table 1). Landrace sows possessed significantly more functional teats than Large White sows (17.20 ± 1.10 versus 15.20 ± 1.10; p = 0.014). Birth weight was similar between breeds, but Large White piglets achieved significantly higher weaning weight (11.48 ± 1.35 kg versus 8.20 ± 1.79 kg; p = 0.012) and average daily gain (182.0 ± 25.3 g/day versus 136.6 ± 42.7 g/day; p = 0.049) by week eight, despite lower early haematological values. All comparisons in Table 1 were conducted at the sow/litter level (n = 5 per breed).

Table 1: Sow, Litter and Piglet Characteristics by Breed

Parameter	Large White (n=5)	Landrace (n=5)	p-value
Sow weight at farrowing (kg)	171.00 ± 12.50	154.00 ± 14.20	0.162
Litter size (piglets born alive)	9.20 ± 1.79	8.20 ± 2.05	0.387
Litter sex ratio (% males)	52.50 ± 14.20	49.50 ± 13.80	0.762
Functional teats (no.)	15.20 ± 1.10	17.20 ± 1.10	0.014*
Birth weight (kg)	1.30 ± 0.34	1.26 ± 0.39	0.841
Weaning weight, week 8 (kg)	11.48 ± 1.35	8.20 ± 1.79	0.012*
Average daily gain (g/day)	182.00 ± 25.30	136.60 ± 42.70	0.049*

*Values are means ± standard deviation. *Significant difference (p < 0.05). Comparisons performed at the sow/litter level (n = 5 per breed).*

Figure 1 illustrates the breed differences in growth performance. Despite starting with lower early haemoglobin, Large White piglets exhibited superior postnatal growth once iron supplementation had been administered, consistent with the known genetic growth potential of the breed under intensive conditions.



Figure 1. Growth performance (weaning weight and average daily gain) of Large White and Landrace piglets at week 8.

Sow Farrowing Weight as a Correlate of Haematological and Growth Outcomes

Table 2 presents the complete exploratory multiple-regression results. Each additional kilogram of sow farrowing weight was associated with a reduction of 0.042 g/dL in early haemoglobin concentration (SE = 0.018, t = −2.33, approximate 95 % CI −0.078 to −0.006; p = 0.022) and 0.118 percentage points in early packed cell volume (SE = 0.051, t = −2.31, p = 0.023). Each additional piglet born alive was associated with a 0.287 g/dL reduction in early haemoglobin (approximate t ≈ −1.98, p < 0.05). Each 10-percentage-point increase in the proportion of male piglets was associated with a 0.041 g/dL reduction in early haemoglobin (approximate t ≈ −2.24, p = 0.027). The overall model for early haemoglobin was highly significant (F ≈ 159.6, model p < 0.001) and explained a substantial proportion of the observed variation (R^2 = 0.833, adjusted R^2 = 0.733). Variance-inflation factors for all predictors remained below 2.0. Sow farrowing weight was positively associated with weaning weight and average daily gain but unrelated to birth weight. None of the three predictors retained a detectable association with haemoglobin or packed cell volume at week 8.

This pattern is consistent with the hypothesis advanced by Krogh *et al*. (2021) that maternal body composition may influence nutrient partitioning and the availability of micronutrients such as iron to individual foetuses when heavier sows support larger, more productive litters. The present study did not measure maternal iron stores, placental iron transfer or milk iron concentration directly; the nutrient-partitioning explanation therefore remains a plausible biological hypothesis rather than a demonstrated mechanism. Maintaining sow farrowing weight within a moderate range may help balance early haematological status against the benefits of maternal productivity for post-weaning growth.

Litter Size as a Correlate of Early Haematological Status

Litter size ranged from six to twelve piglets born alive (overall mean 8.70). In the joint exploratory model, each additional piglet born alive was associated with a 0.287 g/dL reduction in early haemoglobin concentration ($p < 0.05$). A comparable negative directional association was observed for early packed cell volume. Litter size was not significantly associated with birth weight, and by week 8 the association with haemoglobin and packed cell volume was no longer detectable. This pattern is directionally consistent with reports that piglets from larger litters experience greater competition for colostrum and functional teats and consequently lower early haemoglobin (Schmitt *et al*., 2021; Pedersen *et al*., 2020; Starzyński *et al*., 2024).

Litter Sex Ratio as a Correlate of Early Haematological Status

Litter sex ratio averaged 51.1% males (range 33.3–75.0%), with no significant breed difference. Each 10-percentage-point increase in the proportion of male piglets was associated with a 0.041 g/dL reduction in early haemoglobin concentration ($p = 0.027$). A similar negative directional effect was observed for packed cell volume. No association was found with birth weight, and the sex-ratio association had resolved completely by week 8. Male piglets typically grow faster than female littermates in early life, which could plausibly raise metabolic and iron requirements (Mori *et al*., 2021). The present data cannot distinguish an iron-specific mechanism from a more general effect of faster growth on haemoglobin status; the association is therefore interpreted as correlational. The association resolves by week 8, suggesting that routine iron supplementation is sufficient to eliminate the sex-related disparity before weaning and underscoring the value of identifying male-biased litters at birth for closer early monitoring.

Table 2: Exploratory Multiple Regression Results for Sow Farrowing Weight, Litter Size and Litter Sex Ratio as Correlates of Piglet Outcomes

Predictor	Outcome	B	SE	Approx. 95% CI	p
Sow weight (kg)	Early Hb (g/dL)	−0.042	0.018	−0.078, −0.006	0.022*
Sow weight (kg)	Early PCV (%)	−0.118	0.051	−0.219, −0.017	0.023*
Sow weight (kg)	Birth weight (kg)	0.005	0.008	−0.011, 0.021	0.533
Sow weight (kg)	Weaning weight (kg)	0.068	0.031	0.006, 0.130	0.031*
Sow weight (kg)	ADG (g/day)	1.12	0.51	0.11, 2.13	0.030*
Litter size (piglets)	Early Hb (g/dL)	−0.287	≈0.145	≈ −0.57, 0.00	<0.05*
Sex ratio (per 10% ♂)	Early Hb (g/dL)	−0.041	≈0.018	≈ −0.077, −0.005	0.027*

*B (β) = unstandardised regression coefficient with the other two predictors held constant; SE = standard error; CI = approximate 95 % confidence interval. Corresponding t-statistics (t = B/SE): sow weight on early Hb t = −2.33; sow weight on early PCV t = −2.31; litter size on early Hb t ≈ −1.98; sex ratio on early Hb t ≈ −2.24. Full model for early haemoglobin: R^2 = 0.833, adjusted R^2 = 0.733, F(3, ≈96) ≈ 159.6, model p < 0.001. Variance-inflation factors (VIFs) for all three predictors were < 2.0. Because the predictors are litter-level attributes, the effective sample size is approximately 10 independent clusters; results are therefore exploratory rather than confirmatory. Residual diagnostics showed no gross departures from model assumptions. *p < 0.05.*

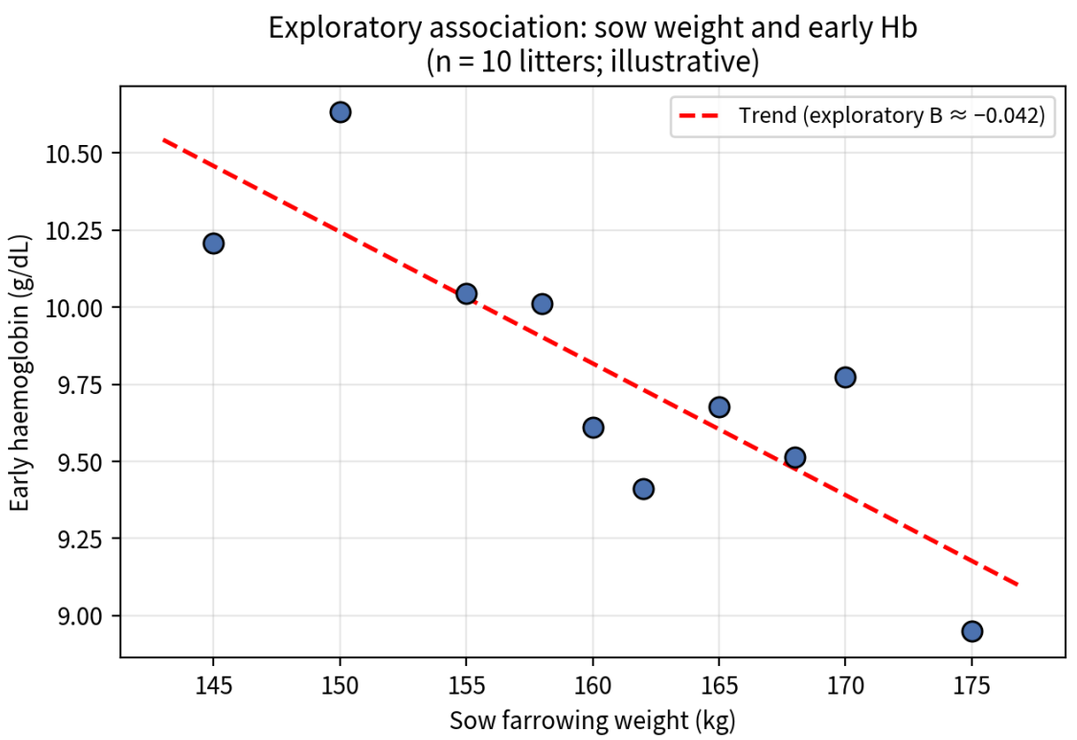


Figure 2. Exploratory association between sow farrowing weight and early haemoglobin concentration (illustrative scatter with fitted trend; n = 10 litters).

Breed Differences in Early Haematological Profile and Functional Teat Number

At days 3–5, Landrace piglets recorded numerically higher haemoglobin (7.64 ± 0.66 g/dL) and packed cell volume (23.68 ± 1.63 %) than Large White piglets (6.64 ± 0.98 g/dL and 20.60 ± 3.78 %). Early red-blood-cell and white-blood-cell counts were also significantly higher in Landrace piglets ($p < 0.05$). By week 8, after routine iron supplementation, haematological values had improved substantially in both breeds and breed differences were no longer statistically significant (Figure 3).

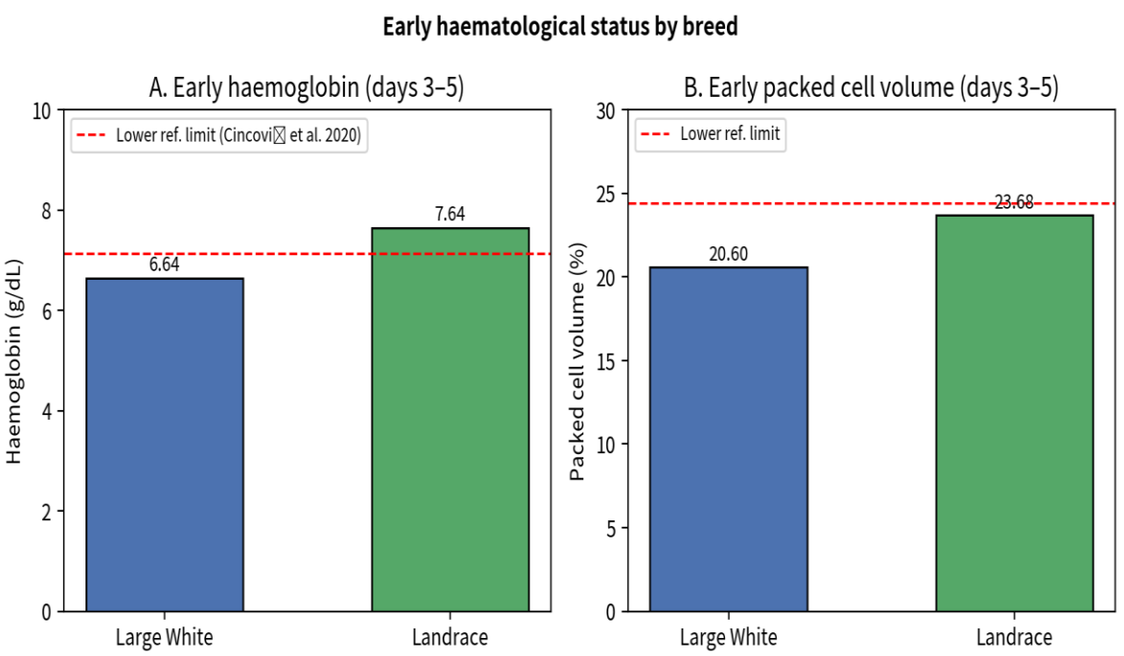


Figure 3. Early (days 3–5) haemoglobin concentration and packed cell volume by breed, with reference lower limits from Cincović et al. (2020).

The significantly higher functional teat counts in Landrace sows (Table 1) plausibly helps explain their more favourable early haematological profile. The ratio of piglets born alive to functional teats, an indicative measure of nursing pressure, was numerically higher in Large White litters (≈ 0.61 piglets per teat) than in Landrace litters (≈ 0.48) (Figure 4). More functional teats are expected to reduce suckling competition and allow more consistent access to colostrum and milk, consistent with Gutiérrez *et al*. (2020) and Wahyuni *et al*. (2022). Functional teat number was not entered as a formal regression term; the observation is therefore presented as an associated protective factor rather than a tested predictor.

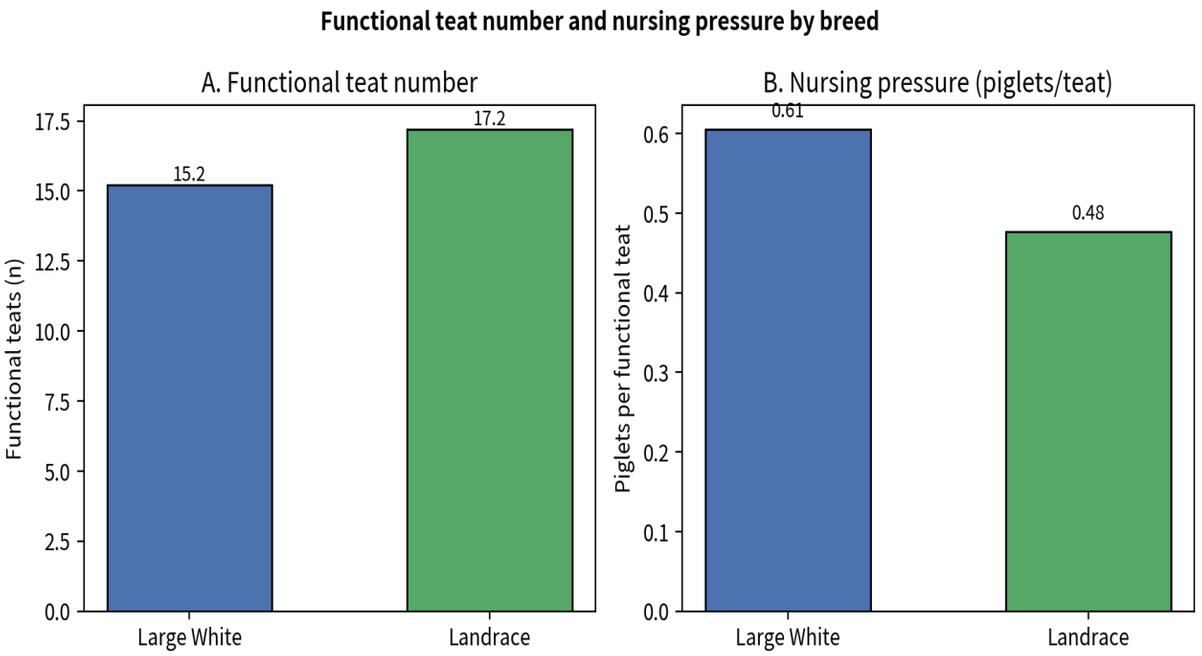


Figure 4. Functional teat number and piglets-per-teat (nursing pressure) by breed.

Limitations

The study is constrained by the small number of independent litters (n = 10), purposive selection from a single commercial farm, absence of an untreated control group, lack of direct iron-status biomarkers (serum iron, ferritin, transferrin saturation), unrecorded parity, and the overlapping timing of iron administration and early blood sampling. Parity is a recognised potential confounder: literature indicates that sow iron reserves tend to decline with advancing parity, so the absence of parity data limits interpretation. The geometric weight-estimation formula is a practical farm approximation subject to measurement error relative to actual scale weights. Residual diagnostics and variance-inflation factors did not indicate severe model misspecification, yet the small number of clusters precludes precise estimation or formal validation of a predictive model. Consequently, the findings are exploratory, the reported R^2 is vulnerable to overfitting, and generalisation beyond the studied breeds and production system should be made with caution. External validation on a larger, multi-farm data set that incorporates parity and appropriate cluster-level analysis would be required before any of the associations could be regarded as a practical screening tool.

CONCLUSION

In this observational study of ten intensively managed litters, sow farrowing weight, litter size and litter sex ratio were each associated with lower early haemoglobin concentration and packed cell volume. The associations were no longer detectable at eight weeks of age under the farm's

routine iron-supplementation protocol. Landrace piglets showed more favourable early haematological values, while Large White piglets achieved higher weaning weights and average daily gains. The results suggest that these routinely recorded sow and litter characteristics may help identify litters that warrant closer haematological monitoring in commercial intensive systems. Given the limited number of independent units, the findings should be regarded as exploratory. Larger, multi-site studies that incorporate parity, direct iron-status measures and appropriate cluster-level analysis are needed to confirm the observed associations and to evaluate their practical utility.

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