

Factors influencing piglet average daily gain during the first week of lactation in hyperprolific sow under tropical conditions

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Abstract

Birth weight (BW) is a key determinant of average daily gain (ADG) in piglets; however, hyperprolific sow genetics, particularly under tropical conditions, have increased the proportion of low-birth-weight piglets. This study evaluated factors associated with ADG during the first 7 days of lactation within birth weight categories (<1.0, 1.0–1.3, and >1.3 kg). A total of 1,185 piglets from 97 litters that survived to day 7 were included. Factors analyzed were cumulative birth interval, birth order, colostrum intake per kilogram of body weight, rectal temperature at 24 h postpartum, sex, intrauterine growth restriction (IUGR), and cross-fostering. Birth weight, cumulative birth interval, birth order, colostrum intake, and rectal temperature were significantly associated with ADG. Piglets with high birth weight showed greater ADG (180 ± 4 g/day) than moderate (150 ± 4 g/day) and low birth weight groups (113 ± 5 g/day, $P < 0.001$). Regardless of birth weight, piglets that consumed 300–400 or >400 g colostrum/kg BW had significantly higher ADG than those that consumed <200 or 200–300 g colostrum/kg BW ($P < 0.001$). Within the high birth weight group, longer cumulative birth intervals (>240 min) and later birth order were associated with reduced ADG ($P < 0.05$). Rectal temperature at 24 h positively influenced ADG in moderate and high birth weight groups. Additionally, sex, IUGR, and cross-fostering affected ADG across birth weight categories. These findings emphasize the importance of neonatal vitality and management, particularly optimizing colostrum intake, maintaining thermal status, and appropriate cross-fostering, to improve early growth performance in piglets under tropical conditions.

Keywords: average daily gain, birth weight, colostrum, prolific sow, rectal temperature

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Introduction

It has been reported that pigs with higher weaning weights tend to exhibit better overall performance during the nursery phase and generate greater economic returns compared to lighter-weight pigs (Jaramillo *et al.*, 2025). Consequently, achieving a higher average daily gain (ADG) during the suckling period is desirable to ensure optimal weaning weights. Previous studies have also demonstrated that piglet birth weight significantly influences postnatal litter development, particularly in the early stages of life or prior to weaning (Zotti *et al.*, 2017; Surek *et al.*, 2019). However, the widespread adoption of hyperprolific sow genetics, especially in tropical regions, has contributed to a higher prevalence of small, low-birth-weight piglets (Adi *et al.*, 2024). In addition to genetic and prenatal factors, environmental conditions play a crucial role in piglet growth. Ogawa *et al.* (2022) reported that ambient temperature influences ADG of pigs weighing between 30 kg and 105 kg. Specifically, for every 1 °C increase above 21.1 °C, ADG decreased by 12.6 g, resulting in a longer duration required to reach the target body weight (Ogawa *et al.*, 2022). Therefore, addressing factors that influence ADG during the early lactation period is essential for effective management, particularly in tropical production systems.

A range of health- and management-related factors have been identified as contributing to reduced ADG in suckling piglets. These include medical conditions such as arthritis, diarrhea, and infections, as well as non-infectious issues such as skin abrasions, weak pasterns in sows kept on concrete slats, and poor sow milk production postpartum (Johansen *et al.*, 2004). Many of these factors can be mitigated through appropriate on-farm management practices. However, intrinsic factors related to the piglets themselves, particularly at birth or during the very early stages of life, also warrant attention. Piglet birth weight is widely recognized as a key determinant of neonatal survival and early growth performance (Muns *et al.*, 2016). Low-birth-weight piglets have a limited ability to maintain body temperature (Theil *et al.*, 2014b) and have reduced energy reserves, which may increase their vulnerability during the immediate postnatal period. Birth weight is positively associated with colostrum intake (Juthamanee and Tummaruk, 2021), and piglets with lower birth weights generally exhibit a reduced body-mass index (BMI) (Ngo *et al.*, 2024). BMI has been linked to muscle mass, glycogen storage, and survival probability (Amdi *et al.*, 2013; Ngo *et al.*, 2024). In addition, lighter piglets tend to reach the udder later and are less competitive at the teat than heavier littermates, which may further limit colostrum intake (Dividich *et al.*, 2005; Chaiyapatmaetee *et al.*, 2025). In modern swine production systems, ongoing genetic selection for increased litter size has been accompanied by a reduction in average piglet birth weight (Adi *et al.*, 2024). Despite extensive evidence linking birth weight to neonatal outcomes, limited information is available on the determinants of early postnatal growth among piglets with comparable birth weights, particularly in hyperprolific sows managed under tropical conditions. Therefore, the present study

aimed to evaluate factors influencing ADG during the first week of lactation in piglets with similar birth weights born to hyperprolific sows under tropical conditions, with the objective of identifying modifiable contributors to early growth performance.

Materials and Methods

Animals and study design: This study was conducted in compliance with the Ethical Principles and Guidelines for the Use of Animals for Scientific Purposes established by the National Research Council of Thailand. Ethical approval was obtained from the Institutional Animal Care and Use Committee in accordance with Chulalongkorn university's regulations and policies on the care and use of experimental animals (Approval number 2331034). The study was conducted during the rainy season from June to July and included 1,185 piglets that survived to 7 days of age from 97 litters. Data on the live-born piglets were collected at birth, and at 1 and 7 days of age. At birth, the following data were recorded for each piglet: birth time, birth weight, birth order, viability status (live-born, stillborn, or mummified fetus), sex (male/female), heart rate (beats per minute), blood oxygen saturation (%), presence of meconium staining (yes/no), occurrence of umbilical cord rupture (yes/no), and whether farrowing assistance was required (yes/no). At 1 day of age, the following data were recorded for surviving piglets: body weight (kg) and rectal temperature (°C). Additionally, body weight and whether cross-fostering was performed (yes/no) were recorded for surviving piglets at 7 days of age. An ear tattoo was used to identify each individual piglet. Piglet weight gain at 1 day of age was used to estimate colostrum intake using the formula established by Theil *et al.* (2014a). If the mathematical model produced a negative value, colostrum intake was adjusted to zero. Colostrum intake per kg of piglet body weight was determined by dividing the total colostrum consumed by the piglet's birth weight. ADG was calculated by dividing the weight gain over the first 7 days of age by 7. Additionally, the percentage of weight gain over the first 7 days of age (PWWG) was calculated by dividing the weight gain over 7 days by the birth weight and multiplying by 100. Based on birth weight, piglets were categorized into three groups: low birth weight (<1.0 kg), moderate birth weight (1.0–1.3 kg) and high birth weight (>1.3 kg). Piglet birth order was categorized into quartiles (Q1–Q4) using the formula described by van Dijk *et al.* (2006). Additionally, piglets were categorized according to cumulative birth intervals into three groups (<120 min, 120–240 min and >240 min); colostrum intake per kg of body weight into four groups (<200 g, 200–300 g, 301–400 g and >400 g), and rectal temperature at 1 day of age into four groups (<37.0 °C, 37.0–38.0 °C, 38.1–38.5 °C and >38.5 °C).

Housing and general management: During gestation, gilts and sows were housed in individual stalls (1.61 m²) in the mating facilities. Approximately one week before the expected farrowing date, animals were transferred to individual farrowing pens (4.83 m²). Within the farrowing pens, sows were kept in a

farrowing crate for the whole period of lactation (1.50 m²). The farrowing pens were fully slatted, with concrete slats in the central area for the sow and steel slats on both sides of the farrowing crate for the piglets. Each pen was equipped with a designated creep area for piglets (0.60 m²), fitted with a plastic hover and an infrared heating lamp to maintain an ambient temperature of approximately 34 °C around farrowing. During the study period, the barn's average daily temperature was 28.4 ± 2.8 °C, while the average relative humidity was 78.0 ± 15.1%. One week leading up to farrowing, the feed allowance was adjusted to 3.0–4.0 kg per sow per day, divided into two equal meals served at 0700 and 1300 h. After farrowing, sows were provided feed *ad libitum*, with an average daily intake of 5.0–6.0 kg during lactation. Water was continuously available through nipple drinkers. The lactation diet consisted of a standard commercial feed, formulated to provide 15.6 MJ ME/kg, 18.9% protein, 2.6% crude fibre, and 1.06% total lysine. Farrowing induction was not performed. An intravenous infusion of 20 mL of a solution containing butaphosphan and cyanocobalamin (vitamin B12; Catosal®, Elanco Animal Health, IN, USA) and 30 mL of calcium borogluconate solution (Kela N.V., Hoogstraten, Belgium), diluted in 1 liter of a solution containing 5.0% dextrose and 0.45% sodium chloride (D5-1/2S®; Thai Nakorn Patana Co. Ltd., Nonthaburi, Thailand), was administered to all sows after the birth of the first piglet. Farrowing supervision was conducted 24/7 to ensure that the farrowing process was closely monitored, and assistance was provided if the birth interval exceeded 45 min or if there was no progress in uterine contractions. Following the delivery of the 10th piglet, all sows were administered 10 IU of oxytocin (Eurovet Animal Health BV, Bladel, The Netherlands) through intravenous infusion. On the day after farrowing, piglets were ear-notched, tail-docked, teeth clipped and received intramuscular injections of 2 mL iron dextran (Ferro10% Plus®, Nova Medicine Co. Ltd., Pathum Thani, Thailand), along with minerals and herbal extracts (Blen-Ionic®, Panomix Nutrisolutions Co. Ltd., Pathum Thani, Thailand). Male piglets were castrated 3 days after farrowing. Cross-fostering of live-born piglets was performed within the first 24–48 h after birth to standardize litter size to approximately 14–15 piglets per sow, regardless of piglet size or body weight. Piglets that were cross-fostered were individually re-identified and included in the statistical model.

Data collection: At birth, each piglet was individually identified in birth order, from the first to the last born, using adhesive tape. The birth interval and cumulative birth interval were recorded for each piglet. The birth interval was defined as the time (in minute) between the delivery of a piglet and that of the immediately preceding piglet, whereas the cumulative birth interval referred to the total time elapsed from the birth of the first piglet to the birth of the individual piglet in question. Farrowing assistance was provided if the birth interval exceeded 45 min, and piglet births involving assistance were recorded. Stillborn piglets and mummified fetuses were identified by their skin color, sunken eyes, and skin condition, then removed

from the crate, while live-born piglets were kept in place. Live-born piglets were further classified by sex and by the presence of meconium staining, identified by a greenish discoloration of the skin, into either normal or meconium-stained groups. Umbilical cord rupture was determined by the presence of blood on the cord or surrounding area and recorded as a binary trait (yes or no). Additionally, liveborn piglets were categorized as either normal or exhibiting intrauterine growth restriction (IUGR) according to the criteria described by Hales *et al.* (2013). Within 5 min of birth, heart rate (beats per min) and oxygen saturation (%) were measured using an H100B Pulse Oximeter (EdanUSA, San Diego, USA) attached to the piglet's foreleg. Live-born piglets were weighed at two time points to determine colostrum consumption: immediately after birth (prior to colostrum intake) and again at 17–24 h post-birth, using a digital scale (SDS® IDS701-C SERIES, SDS Digital Scale Co. Ltd., Yangzhou, China). At 24 h after birth, the rectal temperature of surviving piglets was measured using a digital clinical thermometer (SOS Clinical; BT-A21CN, Fudakang Industrial Co. Ltd., Guangdong, China). Piglet birth order was identified using ear tattoos. Surviving piglets were weighed again at 7 days of age.

Statistical analyses: Statistical analyses were performed using SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA). Descriptive statistics for continuous variables, including sow reproductive traits and piglet characteristics, were generated using the MEANS procedure. Categorical variables, including IUGR characteristics, birth assistance, meconium staining, umbilical cord rupture, and cross-fostering status, were analyzed using the FREQ procedure and are presented as percentages. Pearson's correlation coefficients were calculated using the CORR procedure to evaluate the associations between ADG (g/day) and piglet characteristics, including birth weight (g), birth interval (min), cumulative birth interval (min), birth order, heart rate (beats/min), blood oxygen saturation (%), colostrum intake per kilogram of body weight (g/kg BW), and rectal temperature at 24 h after birth (°C). Piglets that died before 7 days of age were excluded from all analyses to ensure consistent evaluation of growth and performance parameters.

ADG was analyzed using analysis of variance within a general linear mixed model using the MIXED procedure. The fixed effects included birth weight class (<1.0 kg, 1.0–1.3 kg, and >1.3 kg), cumulative birth interval (<120 min, 120–240 min, and >240 min), birth order rank (Q1–Q4), colostrum intake per kilogram of body weight (<200 g, 200–300 g, 301–400 g, and >400 g), rectal temperature (<37.0 °C, 37.0–38.0 °C, 38.1–38.5 °C, and >38.5 °C), sex (male/female), cross-fostering (yes/no), IUGR (yes/no), farrowing assistance (yes/no), umbilical cord rupture (yes/no), and meconium staining (yes/no), including two-way interactions between birth weight classes and the other variables. Litter was included as a random effect to account for clustering of piglets within litters. The piglet was considered the experimental unit. Pre-weaning weight gain (PWWG) was analyzed using the

same model. Least-squares means were compared using the least significant difference test. Model assumptions were evaluated by examining the normality of residuals and homogeneity of variance. Statistical significance was defined as $P < 0.05$.

Results

Descriptive statistics: Descriptive statistics for sow reproductive traits and piglet characteristics, such as parity, total number of piglets born per litter, number of piglets born alive per litter, number of stillbirths per litter, number of mummified fetuses per litter, piglet birth weight, body weight at 24 h after birth, body weight at day 7 after birth, colostrum intake per kg of piglet body weight, rectal temperature at 24 h after birth, heart rate, blood oxygen saturation, birth interval, ADG during the first week of lactation, as well as the proportions of piglets born with farrowing assistance, cross-fostered piglets, IUGR piglets, piglets with meconium staining, and piglets with umbilical cord rupture, are presented in Table 1. Of piglets, 51.6% were male and 48.4% were female. As shown in Figure 1, the ADG of piglets in the heaviest birth weight group (180 ± 4 g/day) was higher compared to the moderate (150 ± 4 g/day, $P < 0.001$) and low birth weight groups (113 ± 5 g/day, $P < 0.001$). However, the PWWG of piglets in the high birth weight group (83.3 ± 2.5 %) was lower compared to the moderate (90.1 ± 2.5 %, $P = 0.002$) and low birth weight groups (92.5 ± 2.8 %, $P < 0.001$) (Fig. 1).

Factors affecting piglet ADG during the first week of lactation: Pearson's correlations between ADG during the first week of lactation and the characteristics of piglets that survived the first week of lactation are presented in Table 2. Regardless of birth weight, piglets that consumed 300–400 or >400 g colostrum/kg BW had significantly higher ADG than those that consumed <200 or 200–300 g colostrum/kg BW ($P < 0.001$) (Fig. 2). In addition, piglets that consumed >400 g colostrum/kg BW exhibited higher ADG than those consuming 300–400 g/kg BW ($P < 0.001$, Figure 2).

Overall, birth weight, cumulative birth interval, birth order, colostrum intake per kg of piglet body weight, and rectal temperature at 24 h after birth were positively correlated with ADG during the first week of lactation. Figure 3 shows ADG during the first week of lactation across classes of cumulative birth interval, birth order rank, and rectal temperature, within birth weight categories. Interestingly, within the high birth weight group, piglets with a longer cumulative birth interval (>240 min) had a lower ADG compared to those with shorter cumulative birth intervals (120–240 min, $P = 0.030$ and <120 min, $P = 0.016$) (Fig. 3A). Similarly, within the high birth weight group, piglets in the last birth order rank (Q4) had a lower ADG compared to those in Q1 ($P = 0.002$) and Q2 ($P = 0.002$), but did not differ from those in Q3 ($P = 0.075$) (Fig. 3B). Increasing rectal temperature influenced ADG in the moderate and high birth weight groups, but not in the low-birth-weight group (Fig. 3C).

Sex (Fig. 4A), IUGR (Fig. 4B) and cross-fostering (Fig. 4C) significantly affected the ADG of piglets within the birth weight groups. Among piglets with moderate birth weight (1.0–1.3 kg), female piglets exhibited a higher ADG during the first 7 days of life than male piglets ($P = 0.002$). In contrast, no sex-related differences in ADG were observed among piglets with low or high birth weight (Fig. 4A). In piglets with low birth weight (< 1.0 kg), those classified as IUGR showed a lower ADG compared with normal piglets ($P = 0.019$). However, no differences in ADG were detected between IUGR and normal piglets within the moderate and high birth weight categories (Fig. 4B). Cross-fostered piglets exhibited a lower ADG than non-cross-fostered piglets in both the moderate ($P = 0.034$) and high birth weight groups ($P < 0.001$), whereas no difference in ADG was observed in the low-birth-weight group (Fig. 4C). Farrowing assistance ($P = 0.342$), meconium staining ($P = 0.405$), and umbilical cord rupture ($P = 0.380$) did not affect the ADG of piglets within the different birth weight groups.

Table 1 Descriptive characteristics of sows and piglets that survived the first week of lactation (mean $\pm$ SD).

Variables	Mean $\pm$ SD	Range
Sows ($n = 97$)		
Parity number	3.1 ± 2.1	1 – 8
Total number of piglets born per litter	17.8 ± 4.1	7 – 27
Number of piglets born alive per litter	15.5 ± 3.3	7 – 23
Number of stillborn piglets per litter	1.3 ± 1.7	0 – 7
Number of mummified fetuses per litter	0.9 ± 1.0	0 – 4
Piglets ($n = 1185$)		
Birth weight (kg)	1.24 ± 0.31	0.45 – 2.33
Body weight at 24 h after birth (kg)	1.32 ± 0.34	0.45 – 2.54
Body weight at day 7 after birth (kg)	2.31 ± 0.65	0.73 – 4.73
Colostrum intake per kg of piglet body weight (g/kg BW)	309.7 ± 81.5	63.3 – 989.1
Rectal temperature at 24 h after birth ($^{\circ}\text{C}$)	38.1 ± 0.7	34.2 – 39.8
Heart rate at birth (beats/min)	93.8 ± 50.9	23.0 – 303.0
Blood oxygen saturation at birth (%)	87.6 ± 9.9	42.0 – 100.0
Birth interval (min)	15.5 ± 26.2	0.0 – 282.0
ADG during the first week of lactation (g/day)	152.5 ± 64.4	-81.4 – 394.2
Piglets born with farrowing assistance (%)	14.5	
Cross-fostered piglets (%)	17.5	
Piglets with IUGR (%)	9.3	
Piglets with meconium staining at birth (%)	45.0	
Piglets with umbilical cord rupture at birth (%)	33.9	

Table 2 Pearson's correlations between average daily gain (ADG; mean $\pm$ SD = 152.5 $\pm$ 64.4 g/day), proportional weekly weight gain (PWWG), body weight during the first week of lactation, and characteristics of piglets that survived the first week of lactation ($n = 1185$).

Variables	ADG	PWWG	BW at 7 days
Birth weight (kg)	0.421***	- 0.184***	0.775***
Birth interval (min)	NS	NS	NS
Cumulative birth interval (min)	- 0.093**	- 0.102***	NS
Birth order	- 0.119***	- 0.088**	- 0.094**
Heart rate at birth (beats/min)	NS	NS	NS
Blood oxygen saturation at birth (%)	NS	NS	NS
Colostrum intake per kg of piglet body weight (g/kg)	0.354***	0.401***	0.213***
Rectal temperature at 24 h after birth (°C)	0.206***	0.126***	0.197***

NS = not significant ($P > 0.05$); significance is indicated by * $0.01 < P < 0.05$, ** $0.001 < P < 0.01$ and *** $P < 0.001$.

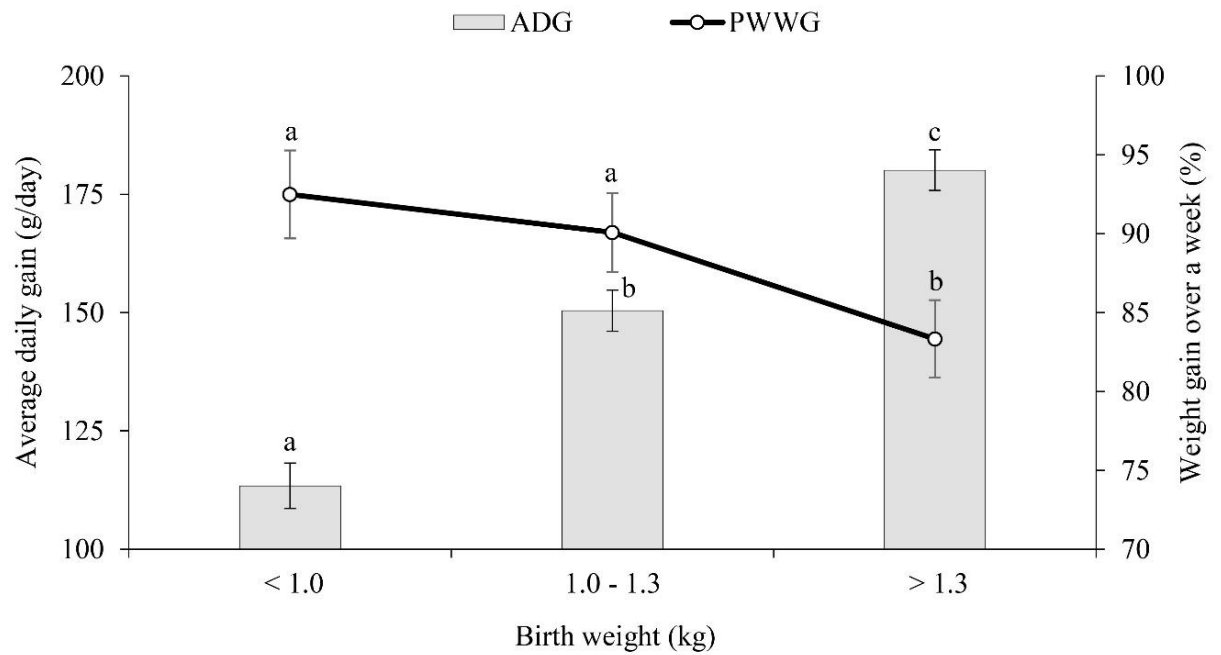


Figure 1 Average daily gain (ADG; g/day) and proportional weekly weight gain (PWWG; %) of piglets surviving to 7 days of age ($n = 1,185$) according to birth weight categories (<1.0 kg, 1.0–1.3 kg, and >1.3 kg). Different superscripts (a–c) within each variable indicate significant differences ($P < 0.05$).

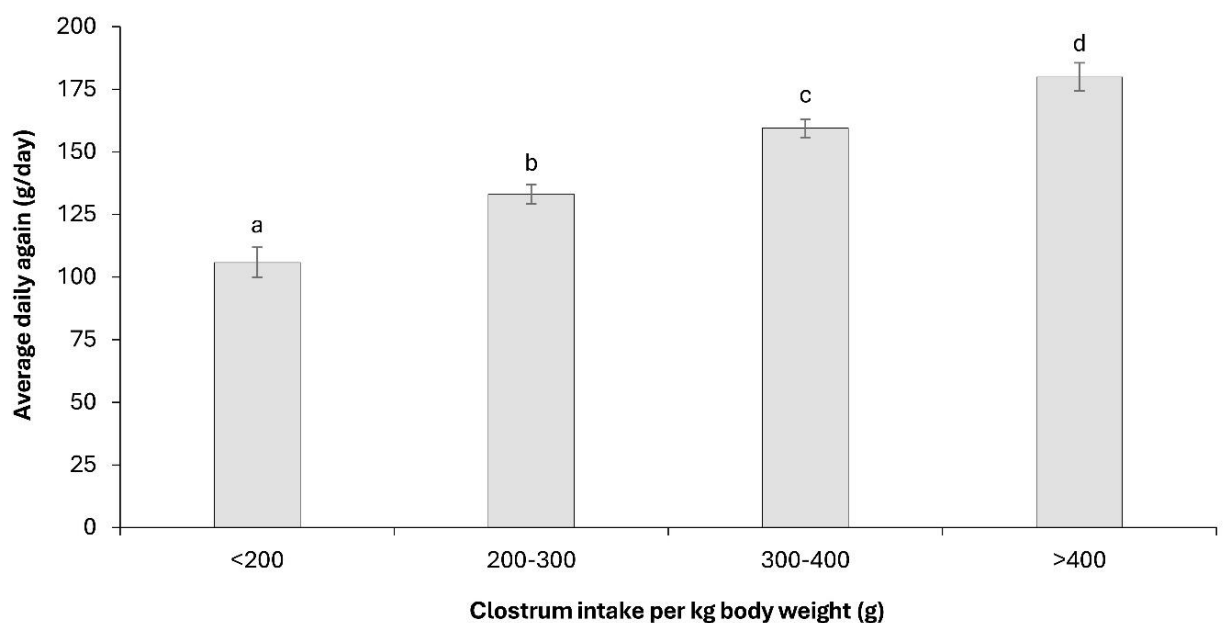


Figure 2 Average daily gain of piglets (g/day) with different colostrum intake per kg body weight. Different superscripts (a–c) indicate significant differences ($P < 0.001$).

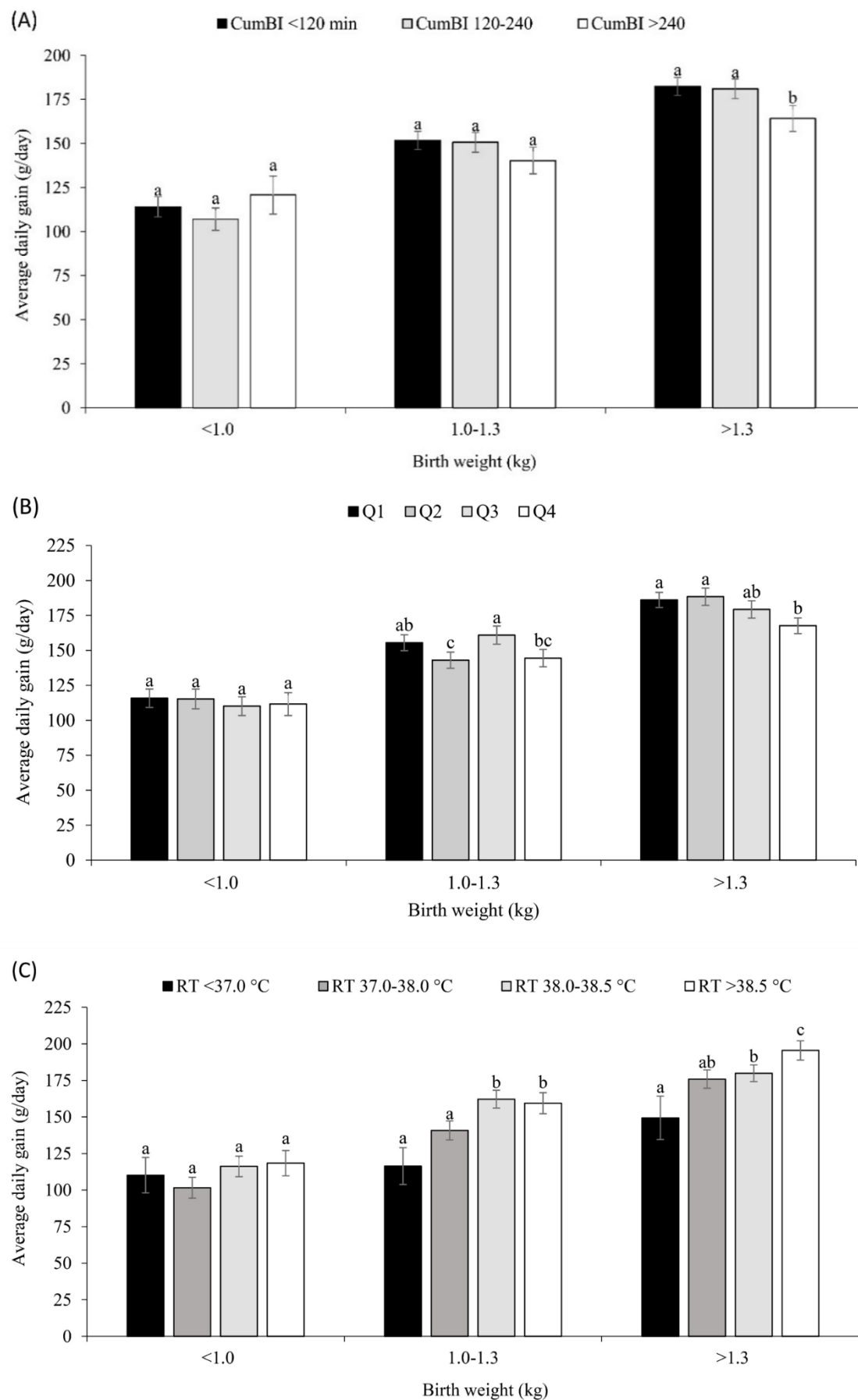


Figure 3 Average daily gain (g/day) during the first week of lactation according to cumulative birth interval (CumBI: <120 min, 120-240 min, and >240 min) (A), birth order rank (Q1-Q4) (B), and rectal temperature (RT: <37.0 °C, 37.0-38.0 °C, 38.1-38.5 °C, and >38.5 °C) (C), within birth weight categories (<1.0 kg, 1.0-1.3 kg, and >1.3 kg). Different superscripts (a, b, c) indicate significant differences ($P < 0.05$).

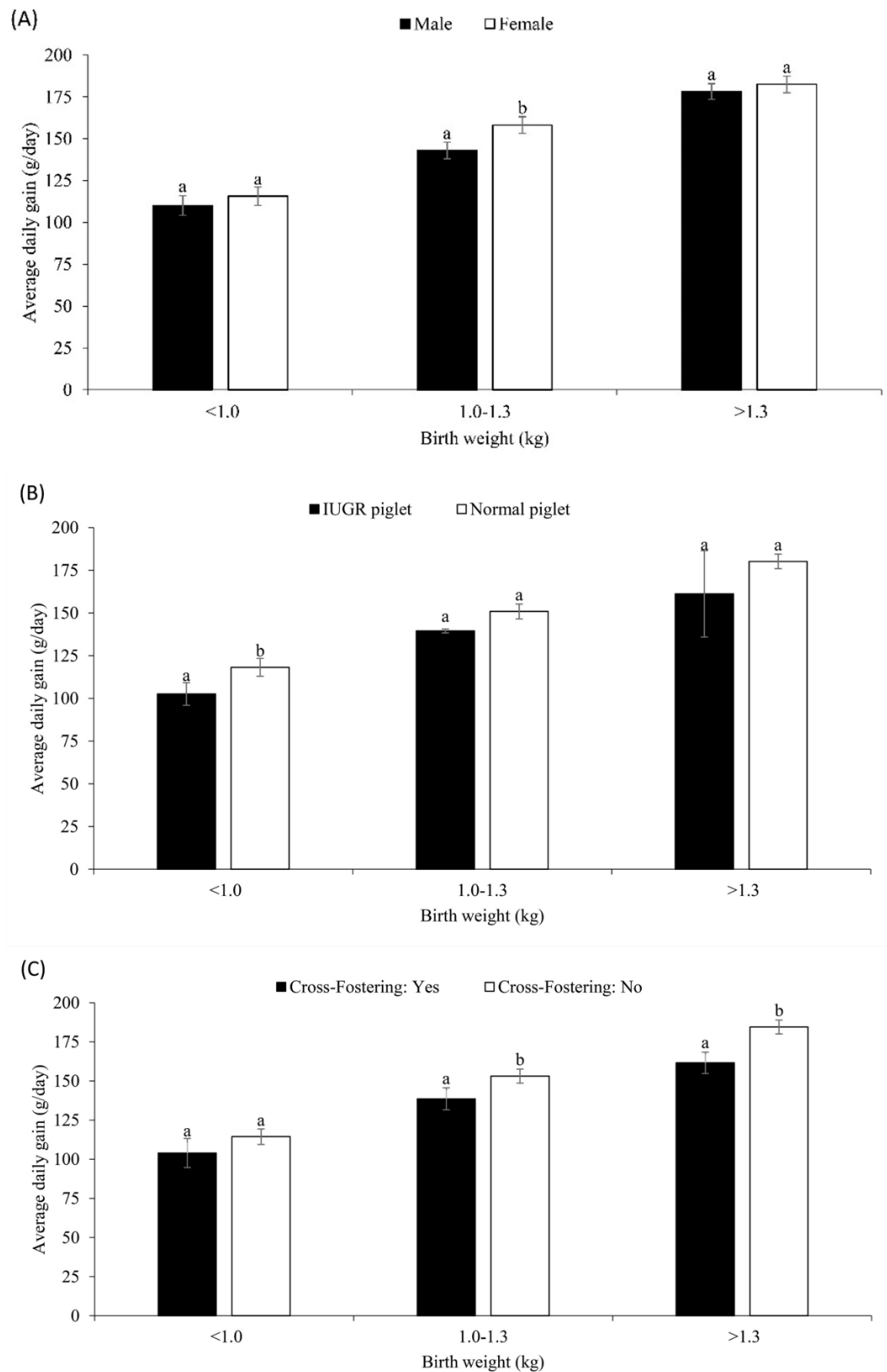


Figure 4 Average daily gain (g/day) during the first week of lactation according to sex (male and female) (A), intrauterine growth restriction (IUGR and normal piglets) (B), and cross-fostering (yes and no) (C) within birth weight categories (<1.0 kg, 1.0-1.3 kg, and >1.3 kg). Different superscripts (a, b) indicate significant differences ($P < 0.05$).

Discussion

The ADG observed during the first week of lactation in this study was consistent with previous reports. Johansen *et al.* (2004) reported an ADG of 208 ± 56 g/day in Danish litters (birth weight: 1.54 ± 0.38 kg), while Surek *et al.* (2014) observed ADG values of 190 ± 35 , 201 ± 33 , and 208 ± 37 g/day in low, intermediate, and high birth weight piglets, respectively, over a 21-day suckling period. In the present study, high birth weight piglets exhibited greater ADG during the first 7 days of suckling compared with moderate (+19.7%) and low (+58.8%) birth weight groups. However, their (PWWG) was lower than that of moderate (-7.5%) and low (-9.9%) birth weight piglets, indicating that lighter piglets achieved greater relative growth efficiency despite lower absolute gains. This finding highlights the importance of evaluating growth relative to initial body weight rather than relying solely on absolute ADG. Consistent with this interpretation, Surek *et al.* (2014) demonstrated that piglets with high birth weight, but low suckling-phase growth were lighter at weaning than low birth weight piglets with high growth, although this difference was reversed by the end of the nursery period. Moreover, when litters were standardized by birth weight, ADG during suckling was not significantly associated with birth weight, suggesting that postnatal factors play a more critical role in early growth performance. Collectively, these findings indicate that early postnatal growth is not solely determined by birth weight but is strongly influenced by perinatal and early-life factors, including cumulative birth interval, birth order, neonatal thermoregulation, and colostrum intake. Optimizing these factors may therefore be essential to improve early growth performance, particularly in piglets with lower birth weights.

The present study demonstrated that cumulative birth interval and birth order were negatively associated with ADG during the first 7 days of lactation, whereas colostrum intake per kilogram of piglet body weight and rectal temperature at 24 h after birth were positively correlated with ADG. These findings underscore the importance of efficient farrowing and early neonatal vitality, reflected by adequate colostrum intake and stable thermoregulation, for optimal early piglet growth (Juthamanee *et al.*, 2024). Juthamanee *et al.* (2024) reported that average colostrum production was 5.5 ± 1.7 kg, with mean IgG and IgA concentrations of 54.9 ± 24.6 mg/mL and 7.6 ± 3.5 mg/mL, respectively. Primiparous sows exhibited a significant 25.2% reduction in IgG concentration within 6 h postpartum, whereas no such decline was observed in multiparous sows. Moreover, multiparous sows produced greater colostrum yields and had higher IgA concentrations than primiparous sows. Consequently, piglets with higher vitality that receive colostrum earlier are more likely to achieve improved growth performance during the first week of lactation. In the present study, the effect of cumulative birth interval on ADG was evident only in the high birth weight group. High-birth-weight piglets with a cumulative birth interval longer than 240 min exhibited lower ADG compared

with those born within 240 min. Similarly, piglets in this group born in the final birth order quartile had lower ADG than those born in the first and second quartiles, suggesting reduced vitality among piglets delivered during the later stages of farrowing. These findings are consistent with Uddin *et al.* (2022), who reported that piglets born in later birth order quartiles had lower vitality scores, although ADG did not differ significantly among birth order groups. Collectively, these results indicate that piglet vitality is closely linked to colostrum intake and subsequent growth, as more vital piglets consume greater amounts of colostrum shortly after birth and achieve higher body weights at weaning (Uddin *et al.*, 2022). In addition, piglets born with meconium staining, an indicator of intrapartum hypoxia, are more frequently observed when the cumulative expulsion interval exceeds 240 min (Mota-Rojas *et al.*, 2012; Laothong *et al.*, 2024). Reduced vitality and shorter suckling duration during the first 24 h postpartum may therefore limit colostrum intake (Uddin *et al.*, 2022; Grahofner and Plush, 2023). In agreement with previous studies, greater colostrum intake in the present study was associated with higher ADG during the first week of lactation across all birth weight groups. Devillers *et al.* (2011) demonstrated that colostrum intake plays a critical role in early piglet growth and survival and also affects subsequent growth performance later in lactation. Similarly, Declerck *et al.* (2016) reported long-term effects of colostrum intake on piglet mortality and performance, particularly in litters from hyperprolific sows. Colostrum intake is also positively associated with rectal temperature at 24 h after birth, reflecting its importance in thermoregulation during the early neonatal period (Devillers *et al.*, 2011).

The reduced ADG observed in high-birth-weight piglets born in the final birth order quartile may partly be explained by intrapartum hypoxia associated with prolonged farrowing (Chaiyapattamattee *et al.*, 2025). During parturition, repeated uterine contractions temporarily reduce uteroplacental blood flow, which may compromise oxygen delivery to fetuses remaining in the uterus for longer periods. Consequently, piglets born later in the farrowing sequence are more likely to experience transient hypoxia and metabolic acidosis before birth (Poolpong *et al.*, 2026). Even in heavier piglets with greater physiological reserves, reduced oxygen availability may impair neonatal vigor, delay standing and suckling behavior, and reduce competitiveness for early colostrum intake, thereby negatively affecting early growth performance (Nuntapaitoon *et al.*, 2018). Hypoxia may also disrupt neonatal energy metabolism and thermoregulation during the first hours postpartum (Pedersen *et al.*, 2015). The absence of a significant difference between Q4 and Q3 piglets suggests that these detrimental effects become most evident during the very late stages of farrowing, when cumulative fetal stress is greatest. Collectively, these findings indicate that early piglet growth is influenced not only by birth weight but also by periparturient physiological stress associated with prolonged farrowing. Piglets born later in the farrowing sequence may experience reduced vitality due to intrapartum hypoxia, which can impair early suckling behaviour and colostrum intake. Therefore,

management strategies aimed at minimizing farrowing duration and supporting neonatal vitality, such as timely farrowing supervision and interventions to ensure adequate colostrum intake, may improve early growth performance in piglets born to hyperprolific sows under tropical production conditions.

In the present study, lower rectal temperatures were associated with reduced ADG in piglets from the moderate- and high-birth-weight groups, consistent with evidence that early postnatal hypothermia impairs growth performance (Pedersen *et al.*, 2015). Pedersen *et al.* (2015) demonstrated that the lowest rectal temperature recorded within the first 24 h after birth had a lasting negative impact on ADG; piglets with a minimum temperature of 32.8 °C exhibited an ADG approximately 19 g/day lower than those maintaining 37.3 °C. The detrimental effect of hypothermia on early growth is likely mediated through several physiological mechanisms (Villanueva-García *et al.*, 2021). Newborn piglets have limited energy reserves, minimal insulation, and an underdeveloped thermoregulatory capacity, making them highly dependent on colostrum intake for both energy supply and thermogenesis (Adi *et al.*, 2025). A decline in body temperature increases maintenance energy requirements, diverting energy away from growth toward heat production (Villanueva-García *et al.*, 2021). In addition, hypothermia reduces piglet vigor and mobility, thereby impairing timely access to the udder and decreasing colostrum intake, which further exacerbates energy deficiency and compromises passive immunity acquisition (Villanueva-García *et al.*, 2021). This creates a negative feedback loop in which low body temperature and inadequate colostrum intake jointly limit early growth performance. These findings highlight the importance of targeted management of piglets born during the terminal stages of farrowing, which are particularly susceptible to hypoxia, delayed suckling, and thermal stress. Optimizing thermal support immediately after birth, ensuring rapid colostrum intake, and minimizing prolonged farrowing duration are therefore critical strategies to enhance neonatal vitality and improve early growth performance under tropical conditions.

Other piglet-related factors affecting ADG in the present study included sex and the incidence of IUGR. Previous research has shown that male piglets have higher ADG than females (169.1 ± 3.7 vs. 157.6 ± 3.9 g/day) at 7 days after birth (Nuntapaitoon *et al.*, 2018). In the present study, however, all male piglets were surgically castrated at 3 days of age as part of routine herd management. Interestingly, males exhibited lower ADG than females, particularly within the moderate birth weight group. This finding is consistent with previous reports indicating that castration in males is negatively associated with ADG (Johansen *et al.*, 2004). Furthermore, Morales *et al.* (2017) reported that castration performed between 3 and 6 days of age in heavier piglets (top 25%) tended to reduce ADG during the suckling period (28 days). However, this reduction in growth appears to be transient, as Kielly *et al.* (1999) observed that differences in growth performance between castrated and intact piglets

diminished by weaning. These findings suggest that, although castration may temporarily impair growth during the early suckling period, compensatory growth mechanisms allow piglets to recover prior to weaning. Therefore, postponing castration beyond 3 days of age may help maximize growth during the neonatal period (Kielly *et al.*, 1999). In addition, growth retardation originating during the foetal period results in IUGR piglets, which typically present with lower birth weights, reduced colostrum intake, and impaired thermoregulation (Chaiyapatmaetee *et al.*, 2025). The present study confirmed that IUGR piglets exhibited reduced ADG during the first 7 days of suckling compared with normal piglets, particularly within the low-birth-weight group. In addition to reduced ADG, previous research has shown that the proportion of IUGR piglets is higher among those that die between 1 and 7 days after birth compared with survivors (Adi *et al.*, 2025). These findings highlight the importance of considering both sex-related factors, particularly the timing and effects of castration, and the presence of IUGR when developing management strategies aimed at optimizing early piglet growth.

The present study demonstrated that cross-fostering, as a management practice, influenced piglet ADG during the first 7 days of lactation in the moderate and high birth weight groups, with fostered piglets exhibiting lower ADG than their non-fostered counterparts. Similarly, Zhang *et al.* (2021) reported a negative impact of cross-fostering on ADG in piglets with birth weights ranging from 0.8 to 1.15 kg. Cross-fostering is routinely practiced in commercial herds to optimize neonatal management, maintaining litter sizes at approximately 14–15 piglets per sow. Nevertheless, ensuring an adequate number of functional teats is critical, particularly when all sows within a batch produce large litters, to reduce competition and facilitate uniform access to nutrition. Moreover, the timing of cross-fostering plays a crucial role in its success, as piglets require sufficient opportunity to consume colostrum prior to being fostered, which is essential for early immunity and growth (Farmer and Edwards, 2022). Supporting this, Zhang *et al.* (2021) demonstrated that piglets cross-fostered at 7 days after birth exhibited significantly higher plasma cortisol concentrations at 21 days of age, indicating elevated stress, compared with those cross-fostered within 36–48 h postpartum. Cross-fostered piglets often face challenges in adapting to a new environment, including acceptance by a different sow and competition with unfamiliar littermates, which can temporarily impair nursing success and growth performance (Zhang *et al.*, 2021). Collectively, these findings highlight that, while cross-fostering is a valuable management tool in hyperprolific herds, careful consideration of timing, piglet selection, and the sow environment is essential to maximize piglet welfare and growth outcomes. Such strategies should be integrated with other farrowing-related factors, including cumulative birth interval and birth order, as well as biological factors identified in this study, such as birth weight, colostrum intake, rectal temperature, sex, and IUGR, to comprehensively improve early piglet survival and development.

In conclusions, the present study demonstrates that birth weight is a major determinant of ADG in piglets born to hyperprolific sows under tropical conditions. Even within similar birth weight categories, piglets delivered during the final stages of farrowing exhibited lower ADG during the first week of lactation, suggesting that prolonged parturition may compromise early postnatal growth. Colostrum intake and rectal temperature measured at 24 h postpartum were also important predictors of ADG, highlighting the importance of early vitality and adequate colostrum consumption for neonatal growth. In addition, male piglets subjected to surgical castration at 3 days of age, IUGR piglets, and those cross-fostered within 24–48 h after birth showed reduced ADG, indicating that both physiological constraints and early-life management practices influence growth during the first week of life. Overall, while birth weight remains a key determinant of early growth performance, factors related to parturition dynamics, neonatal vitality, and management practices, including prolonged farrowing, inadequate colostrum intake, low rectal temperature, castration, IUGR, and early cross-fostering, can further influence ADG during the first week of life. These findings emphasize the importance of optimizing farrowing management and early-life care to improve piglet growth and survival in highly prolific sow herds.

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