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Enhancing reproductive efficiency in commercial pig farms: A scientific review on critical sow and litter-level indicators

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Abstract
Producers are encouraged to optimize the reproductive capacity of sows throughout their lifespan to mitigate production costs and enhance economic efficiency within commercial breeding herds. Due to their early maturity, shorter generation intervals, high fecundity, superior feed conversion efficiency, and nutritional value, pigs are well-suited for intensive farming with minimal maintenance. While pig farming is often regarded as a highly profitable livestock enterprise, it faces numerous productivity challenges. These include issues such as suboptimal reproductive performance, susceptibility to diseases and parasites, and the high costs associated with animal feeds and veterinary drugs. Given that the primary factors contributing to profitability in pig farming are largely related to reproduction, including high prolificacy and a short generation interval, addressing concerns over poor reproductive performance becomes crucial. Various factors serve as key indicators of the reproductive performance of selected animals within a breeding herd. These indicators can be broadly categorized as sow-level and litter-level factors, aiding in the prediction of an animal's future performance in their herd. Given that reproductive traits have low heritability, retaining animals with subpar performance can burden farmers, diminishing economic viability and overall profitability of the farm. Therefore, the meticulous evaluation and selection of animals within breeding herds are crucial, complemented by effective management practices.

Keywords: Total number born, total number born alive, weaning to estrous interval, pre-weaning mortality, ADG

Introduction

The economic success of pig farming hinges on the effective breeding of animals. Key to this is the reproductive success of both sows and boars, as it directly impacts the overall production metrics. For sows, the number and consistency of offspring are crucial indicators of reproductive health. Specifically, sows that produce larger and more consistent litters are linked to increased piglet output per sow annually (Da Silva *et al.*, 2016) [15]. Moreover, uniform litters are correlated with reduced mortality rates before weaning (Quesnel *et al.*, 2012) [65] and enhanced growth rates after weaning. Nonetheless, these reproductive traits are not highly heritable and are influenced by a myriad of genetic and environmental elements (Quesnel *et al.*, 2014) [66].

Pigs frequently experience significant prenatal deaths, which poses a significant challenge to achieving large litter sizes at birth (Da Silva *et al.*, 2016) [15]. Intrauterine growth restriction (IUGR), a prevalent reproductive issue in pigs and other mammalian species, stems from alterations in the in-womb environment. This condition impacts prenatal mortality rates and compromises both fetal growth and subsequent post-birth productivity (Lyderik *et al.*, 2023) [46]. Various factors influence the reproductive efficiency and lifespan of pigs chosen for breeding. These factors can be broadly categorized into two levels: individual sow factors and herd-related factors. Individual sow factors, such as the sow's parity, rising ambient temperatures, reduced feed intake during lactation, and low birth weight, have a more pronounced impact than herd-related factors, which include sows from less productive herds, late insemination, age disparities, and inadequate space allocation (Koketsu *et al.*, 2017) [41].

Currently, it's recognized that monitoring and managing the body condition of sows during gestation is crucial for optimizing reproductive outcomes (Cheng *et al.*, 2019) [12] because physical condition of sows at mating directly affects the reproductive performance of their offspring (Renan *et al.*, 2018) [69].

Thus, there are several factors influence the reproductive longevity of pigs within a breeding herd. By critically analyzing the previous reproductive history of an individual animal, we can predict its future performance whereas this predictive assessment can be conducted at both the sow and litter levels. In this review, we adopt a holistic approach to evaluate and forecast the critical indicators of reproductive performance of pigs in a breeding herd pertaining to both sows and litter.

Reproductive performance in pigs

The economic viability of pig production is intricately tied to the reproductive process, and the reproductive performance of sows hinges on factors related to both litter size and farrowing intervals (Szostak and Katsarov, 2013) [81]. In terms of litter size, critical parameters encompass the total number of piglets born per litter, the count of piglets born alive, the number of stillborn piglets, and the quantity of piglets successfully weaned per litter. Farrowing intervals, on the other hand, encompass the duration of gestation, lactation, and the interval from weaning to conception, with the latter two periods combined to form the farrowing-to-conception interval. These aspects collectively play a pivotal role in shaping the overall reproductive success and economic outcomes in pig farming (Nowak *et al.*, 2020) [57]. The heritability of reproductive traits is commonly reported to be low (Nagyne Kiszlinger *et al.*, 2013 [51]; Sevon-Aimonen and Uimari, 2013) [76] and environmental factors such as nutrition, housing, and management practices play a significant role in shaping reproductive phenotypes. The overview of various indicators of reproductive performance in pigs is summarized in Figure 1.

Sasaki *et al.*, (2011) [73] emphasized that the overall reproductive success of female pigs can be characterized by their longevity in the breeding herd, the number of piglets born alive (PBA), the cumulative count of weaned piglets, and the total days of unproductive sow life. Reproductive success in pigs encompasses both fertility and prolificacy aspects (Soede *et al.*, 2011) [78]. To optimize production efficiency and address economic challenges in commercial pig farming, sustaining a sow's reproductive performance throughout her life is paramount. Also, enhanced reproductive longevity directly contributes to maximizing profits from the herd (Stalder *et al.*, 2012) [80]. According to Nikkila *et al.*, (2013) [56], the primary reason for culling sows is the deterioration of their structural and reproductive health. This underscores the need for simultaneous improvements in genetic traits related to structural soundness and reproductive capabilities, alongside advancements in management practices, to bolster the overall lifetime productivity of pigs.

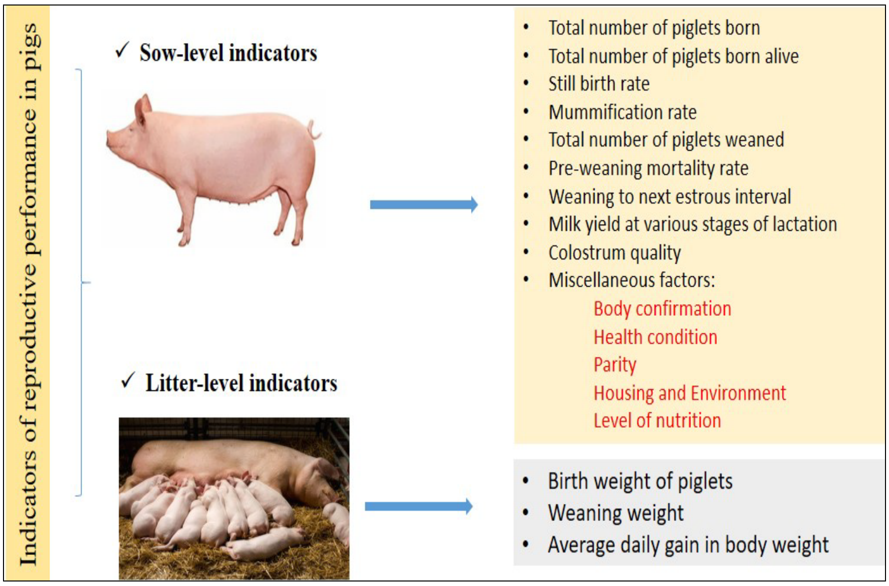

Fig 1: The overview of various indicators of reproductive performance in pigs

Factors influencing reproductive performance in pigs

Parity: Koketsu and Iida, (2017) [41] reported that parameters such as the weaning-to-first-mating interval and weaning-to-next-conception interval are higher in sows with first parity compared to other parity groups. Additionally, weaning weight is lower in this specific parity group. It is observed that traits such as the number of live births and weaning litter size increase with an increase in parity, as these traits are more correlated. Ajay *et al.*, (2023) [3] noted that as parity increases, the likelihood of stillbirths, pregnancy loss, and embryonic mortality also increases. Furthermore, parity influences major reproductive performances with a more homogeneous nature observed between different litters, particularly noticeable between the first and second litters (Quesnel *et al.*, 2008) [64].

Hoving *et al.*, (2011) [27] highlighted that the future performance of the animal is affected by first parity. Confirming this relationship, Knecht *et al.*, (2015) [40] observed that the peak of production performance is seen in the third parity, after which it begins to decrease. Hagan and Etim, (2019) [26] indicated that the parity of the animal significantly affects reproductive traits such as litter size at birth and weaning, rate of farrowing, and birth weight of the piglets. It is observed that as parity increases, litter size at birth and weaning tends to decrease (Piñán *et al.*, 2021) [63].

Body condition

John *et al.*, (2020) [30] observed that the annual replacement rate for gilts has been rising and currently stands at an average of 45%. This increase is primarily attributed to issues of lameness and reproductive challenges. The criteria for selecting gilts for replacement focus on factors such as body condition, overall growth performance, and the reproductive history of their mothers. Also, Lavery *et al.*, (2019) [45] highlighted that the body condition of a sow during mating and early gestation significantly influences both weaning and lactation performances. Several criteria can be used to assess the body condition of potential breeding animals, including limb health, body condition scoring, body weight, and backfat thickness. Among these, backfat thickness is a commonly utilized and straightforward measure for assessing a sow's body condition (Cheng *et al.*, 2019) [12]. This trait can be accurately measured using A-mode ultrasonography (Roongsitthichai and Tummaruk, 2014) [72]. However, the influence of backfat thickness on reproductive performance can be influenced by various factors such as breed, age, estrous cycle, seasonal variations, parity, and mating techniques (Thongkhuy *et al.*, 2020) [85]. Additionally, factors like the sow's body weight, gestation day, lactation duration, and parity can also impact backfat thickness (Kim *et al.*, 2016; Lavery *et al.*, 2019; Mun *et al.*, 2024) [36, 45, 50].

Maintaining optimal backfat thickness during gestation directly correlates with feed intake during lactation (Lavery *et al.*, 2019) [45]. In pigs body condition scoring typically employs a five-point scale. Sows are visually assessed and assigned scores ranging from 1 to 5 based on the visibility of major bone structures. A score of 3 is considered ideal, indicating that the sow possesses adequate bodily reserves to support reproductive functions (Richard *et al.*, 2000) [70]. According to Ajay *et al.*, (2023) [3]; Sens Junior *et al.*, (2023) [75], body condition scoring remains the predominant method employed by farmers for routine body composition assessment. Thaker & Bilkei, (2005) [84] further added that maintaining optimal feed intake during lactation is essential to prevent the deterioration of a sow's body condition.

Housing conditions

Adequate housing is crucial during the early stages of gestation to safeguard embryos and confirm pregnancy. As gestation progresses into the mid-to-late phases, it becomes essential to ensure optimal nutrition for the enhancement of placental and fetal growth. While there is no observed difference in the quantity of live-born piglets between group housing and individual stall housing, various risk factors influencing reproductive performance are linked to group housing. These factors encompass genetic considerations, bedding quality, floor space allocation, group size, social hierarchy, and parity. Moreover, the incidence of lameness in pregnant pigs is more prevalent in group housing compared to stall housing. Housing conditions during the lactation period play a pivotal role in shielding piglets from potential harm, such as accidental crushing or disease contraction. Additionally, effective housing supports the successful transfer of an ample amount of colostrum from the mother to the piglets. Notably, lactating sows housed in pens exhibit higher pre-weaning mortality rates and lighter litter weights when contrasted with those in crated housing (Koketsu and Iida, 2017) [41].

As per Kim *et al.*, (2016) [36] sows housed in groups exhibited a significantly higher ($p<0.05$) feed intake and a shorter ($p<0.05$) weaning-to-estrus interval in comparison to sows accommodated in stalls. Following weaning, there was a notable reduction ($p<0.05$) in back-fat thickness changes among group-housed sows compared to their counterparts in stalls. The quantity of piglets at weaning, along with growth rate and average daily gain, demonstrated a marked increase ($p<0.05$) in group-housed sows as opposed to those housed in stalls. Throughout the gestation period, sows in group housing exhibited a prolonged walking duration, which was significantly greater ($p<0.05$). Farrowing duration was notably shorter ($p<0.05$), and eating time was significantly higher ($p<0.05$) in group-housed sows compared to their counterparts in stalls.

Nutrition

Throughout pregnancy, the dietary intake should deliver sufficient nutrients to support the sow's upkeep, weight increase, lactation, and the growth of the fetus and placenta (NRC, 2012) [55]. Establishing a well-defined nutritional regimen offers operational benefits, allowing for the targeted provision of specific nutrients during various stages of gestation, eliminating the necessity for multiple diet formulations (Johnson *et al.*, 2022) [31]. During pregnancy, the quality of nutrition plays a pivotal role in shaping the in-womb conditions, thereby influencing the growth and development of embryos and fetuses. Inadequate nutrients in the mother's diet can elevate the occurrences of IUGR and fetal losses. Sows demand meticulous nutritional oversight due to ongoing genetic advancements for increased productivity and a more streamlined body condition. (Ferreira *et al.*, 2021) [25].

Environmental conditions

A decline in fertility and prolificacy is observed during the summer months in pigs (Bertoldo *et al.*, 2012) [7]. Specifically, fertility rates are at their lowest in summer, and sows mated during this season tend to have fewer piglets born alive compared to those mated in winter or spring. Pigs, being short-day breeders, highlight the significance of photoperiod as a crucial factor influencing reproductive performance (Auvigne *et al.*, 2010) [5]. Extensive studies in Asian and European regions have explored the correlations between high temperatures and reproductive outcomes (Iida and Koketsu, 2014) [29]. The prevailing hypothesis suggests that reduced reproductive performance in summer results from a combination of elevated temperatures, which hinder the secretion of GnRH (gonadotropin-releasing hormone), and adversely impact ovarian follicle development, compromising corpus luteum functions and leading to lower progesterone concentrations (Bertoldo *et al.*, 2012) [7].

Utilizing climate data from meteorological stations in proximity to the studied herds, researchers have quantified the relationship between maximum temperatures and sow performance (Iida and Koketsu, 2014) [29]. For instance, an increase in outside temperatures has been associated with a decrease in fertility rates and the total number of pigs born, while concurrently increasing returns, weaning-to-mating intervals, and sow mortality. Also, Knecht *et al.*, (2015) [40] suggest that temperature differences and variations in the availability and duration of photoperiod during a particular season are important factors affecting fertility.

Sow-level reproductive performance indicators in pigs

Total number of piglets born

The indicators of breeding performance in pigs, specifically litter size and the count of piglets born alive, stand as pivotal metrics that significantly influence the economic success of pig production (Sell-Kubiak *et al.*, 2022) [74]. These factors play a critical role in determining the overall profitability of pig farming operations (Knecht *et al.*, 2013) [39]. Dimitrov *et* *al.*, (2010) [20], in their research on the synchronization of estrus in pigs, found that the size of the litter at birth is approximately 9.7±0.29, and at weaning, it is around 8.4±0.32. The average litter size at birth in crossbred animals was noted to be greater than that in indigenous breeds (Nath *et al.*, 2013) [54]. De *et al.*, (2013) [17] stated that the Indian indigenous breed of pig, Nicobari, native to the Andaman and Nicobar Islands, has an average litter size of 7-8 at birth. Tummruk *et al.*, (2010) [88]; Roongsitthichai *et al.*, (2014) [72] observed that the litter size at birth in sows with high, moderate, and low backfat thickness is 13.1±0.5, 12.0±0.4, and 12±0.6, respectively.

Aherne, (2002) reported that the litter size of piglets in crossbred sows is greater than in purebred sows by a factor of 0.25-0.5. In a study conducted by Naskar *et al.*, (2007) [53] on Lumsniang, a crossbred of Meghalaya in India, it was found that these animals have their first farrowing at an average age of 460.4 days, with an average litter size at birth of 7.16. Chiduwa *et al.*, (2008) [13] stated that the average litter size at birth in desi pigs in Zimbabwe is around 7.7 and Dandapat *et al.*, (2010) [16] reported that the Mali breed of Tripura has an average litter size at birth of 8.6±0.4.

Total number of piglets born alive

Patterson *et al.*, (2010) [60] emphasized the significance of the age of gilts at the first mating, asserting that it is more crucial than the age at the first estrus when comparing parameters such as piglets born alive (PBA) and reproductive longevity in commercial herds. Hoving *et al.*, (2011) [27] further supported this view, indicating that the number of pigs born alive at birth is influenced by both genetic and management factors. In a study by Iida and Koketsu, (2014) [38], it was highlighted that sows first mated at an age of 278 days or more exhibited a narrower range of reproductive longevity compared to those mated at an earlier age. Although the PBA for the former group was slightly higher, the difference was negligible. The study also suggested that if an animal has a low number of live births, it is advisable to remove it from the breeding herd to maintain overall farm profitability.

Lavery *et al.*, (2019) [45], echoing findings from Douglas *et al.*, (2014) [21], asserted that the total number of live births and total number of piglets born are correlated with the body condition of the sow. The optimal age for the first mating in sows is within the range of 233-253 days, considering both total live births and minimizing the risk of removal from the herd (Balogh *et al.*, 2015) [6]. Koketsu *et al.*, (2020) [42] reported that an increased age at first mating was associated with the lowest removal parity, reduced herd longevity, lower PBA, fewer total animals weaned, and a higher number of non-productive sow days. These findings collectively underscore the critical role of the age at first mating in influencing various reproductive and longevity parameters in farm herds.

Still birth rate

Vanderhaeghe *et al.*, (2013) [89] defined stillborn as pigs not alive at the time of farrowing, without signs of fetal mummification, and noted that the stillborn rate increases when the birth interval between piglets exceeds the normal range. Ajay *et al.*, (2023) [3] collectively reported an increase in the rate of stillbirths in pigs as parity increases. Additionally, a negative correlation ($p < 0.05$) between stillbirths and backfat thickness has been observed (Roongsitthichai and Olanratmanee, 2021) [71]. Furthermore, an extended weaning-to-estrus interval is associated with higher parity. Hence, it is advisable to avoid animals with low backfat. Oliviero *et al.*, (2010) [59] also documented that the risk of stillbirth and the duration of farrowing are elevated in sows with higher levels of fat.

Iida and Koketsu, (2014) [38] also observed an increase in the rate of stillborn births with parity in pigs. They also noted that external manipulations during dystocia conditions can accelerate the stillborn rate. Thongkhuy *et al.*, (2020) [85] found that the number of still born is comparatively higher in animals with low backfat, particularly in those with 3-6 parities. This suggests a potential correlation between backfat thickness, parity, and the occurrence of stillbirths in pigs.

Mummification rate

Wu *et al.*, (2013) [91] reported that the likelihood of mummification in pigs with larger litter sizes is notably higher, attributed to the limited intra-uterine space. Langendijk and Plush, (2019) [44] investigated factors influencing stillbirth and mummification in pigs, noting that the average birth weight of piglets does not influence their incidence. However, a reduction in the live weight of the sow is identified as a predisposing factor. The study further emphasized that occurrences are more frequent in sows with higher litter sizes, but effective management during gestation and the farrowing period can mitigate these rates.

Ajay *et al.*, (2023) [3] explored mummification and stillbirth in pigs, finding that as litter size increases, the likelihood of mummification also rises. Specifically, if the average litter size exceeds 12, the chance increases by 14.5 times. The study highlighted that this rate is higher in both first parity and older parity animals, and placental characteristics also influence mummification. Nam and Sukon, (2022) [52] identified infections, primarily parvovirus infections, as a major cause of mummification in pigs, in addition to management factors and those related to sow and litter. Raguvaran *et al.*, (2017) [67] investigated various factors affecting the likelihood of mummification and stillbirth in pigs, emphasizing that higher litter size is a major contributing factor. They also highlighted the importance of proper management practices and care in mitigating these occurrences, emphasizing that an increase in the rate ultimately affects the reproductive longevity of the mother.

Total number of piglets at weaning

The number of piglets per sow is a crucial measure of a sow's lifetime reproductive production capacity. Declerck *et al.*, (2016) [18] reported that annually, proficient sows can produce up to 30 piglets after weaning. However, if the litter size increases beyond the normal range, there is a higher likelihood of colostrum inefficiency and a lower growth rate. The quantity of piglets successfully weaned per litter is contingent upon factors such as the number of piglets born alive, their individual birth weights, and the milk production capacity of the sow (Nuntapaitoon *et al.*, 2018) [58].

Koketsu *et al.*, (2017) [41] emphasized that the average range of the number of piglets weaned per sow annually has increased from 15-20 to 25-30 over the last decades to achieve optimum production performance. This highlights the evolving standards in pig production to enhance reproductive efficiency and overall productivity. The proportion of piglets successfully weaned serves as a direct reflection of the maternal instincts and nurturing capabilities of the sow, providing crucial insights into breeding performance. Regrettably, this particular indicator is frequently neglected in research on pig reproduction, much like the percentages associated with piglets born alive and those that are stillborn.

Weaning to next estrous interval

Signs of estrus in sows typically manifest within the third to seventh days following weaning with variations observed in the weaning-to-service interval duration among different breeds (Tummaruk *et al.*, 2000) [87]. Notably, purebred sows tend to exhibit shorter weaning-to-service intervals in comparison to their crossbred counterparts (Knecht and Duziński, 2014) [38], and multiparous sows generally experience briefer intervals than primiparous sows. Also, the duration between weaning and the onset of the next estrus increases when feed intake decreases during suckling and lactation. Quesnel *et al.*, (2008) [64] stated that the duration between weaning and the subsequent estrous occurrence is associated with factors such as litter size, the metabolic state of the animal, and the availability of body reserves. This gap tends to decrease in sows with high litter size, with this effect being more evident in animals with their first parity.

Tummaruk *et al.*, (2010) [88] noted that if the animal takes a longer period to enter estrus after weaning beyond the normal duration of 3-6 days, the fertility rate and the number of pigs born in the subsequent cycle may be lower. The return to estrus after farrowing is related to the age of gilts at the first mating, and it appears that the return of estrus is delayed in the case of older gilts (Tani *et al.*, 2016) [83]. This delay may be influenced by the progesterone profile as well as ovarian and corpus luteal activity (Bertoldo *et al.*, 2012) [7]. These findings collectively underscore the importance of proper feeding, management, and understanding the factors influencing estrous return for optimizing reproductive performance in pigs.

Pre-weaning mortality rate

The primary factor contributing to piglet mortality during the period from birth to weaning is the occurrence of low birth weight in piglets across multiple litters (Canario *et al.*, 2006) [11]. Lighter piglets face challenges, including difficulties in maintaining optimal body temperature, exertion in reaching the udder, and accessing colostrum. Škorput, *et al.*, (2023) [77] suggested that a higher backfat in sows may positively influence litter size. However, they noted that concurrently, pre-weaning litter mortality may increase due to a proportional fall in body weight. Lavery *et al.*, (2019) [45] argued that although a higher body weight of the sow during the late gestation period is correlated with higher reproductive efficiency, it may also lead to a higher pre-weaning mortality rate through reduced weaning litter size. In the case of Burmese pigs, Kadirvel *et al.*, (2019) [33] reported that the average mortality before the weaning period is nearly 17.34 percent, and the average mortality rate after weaning is around 8.9 percent. These findings highlight the complex interplay between sow characteristics, reproductive efficiency, and pre-weaning mortality in pigs, emphasizing the need for a balanced approach to optimize both litter size and piglet survival.

Composition and quality of sow colostrum and milk

Colostrum plays a pivotal role in shaping the piglets' immune system and ensuring their long-term performance. Hence, it's crucial to optimize colostrum consumption within the initial six hours post-birth. After the 24-hour mark, the window for absorption of the substantial antibodies present in colostrum closes, rendering it less effective (Ajay *et al.*, 2023) [3]. Additionally, sows typically produce colostrum in ample quantities for only about 12 hours. By the 20-hour mark, the sow transitions to producing milk rather than colostrum. The sufficient quantity of quality colostrum and milk consumption by the litter is an unavoidable factor in piglet management. The optimum composition of colostrum and milk in sow is given in Table 1 and Table 2.

Table 1: Composition of colostrum in sow

Total soilds (in per cent)	Protein (in per cent)	Fat (in per cent)	Lactose (in per cent)	Total ash (in per cent)	IG G (in mg/ml)	Reference
26.73	16.94	5.55	-	0.677	-	Fahmy, (1972) [23]
22.6	15.8	3.76	2.34	0.635	-	Aguinaga *et al.*, (2011) [1]
26.7	16.6	6.4	2.8	0.68	64.4	Hurly, (2015) [28]
-	16.6	5.3	2.9	-	--	Zhang *et al.*, (2018) [92]
-	-	-	-	--	48.4-134.9	Markowska *et al.*, (2010) [49]

Table 2: Composition of milk in sow

Total solids (in per cent)	Protein (in per cent)	Fat (in per cent)	Lactose (in per cent)	Total ash (in percent)	Ig G (in mg/ml)	References
19	6	7-8	4	0.6-1	-	Hurley, (2015) [28]
18.97	5.46	6.34	-	1.041	-	Fahmy, (1972) [23]
17.9	5.34	5.55	5.69	1.04	-	Aguinaga *et al.*, (2011) [1]
19.5	5.0	7.5	5.1	0.86	1	Hurley, (2015) [28]
-	4.99	7.55	5.11	-	-	Zhang *et al.*, (2018) [92]
-	-	-	-	-	1.1-6.8	Markowska *et al.*, (2010) [49]

Physiological and health parameters

Maneetong *et al.*, (2021) [41], Spörri-Vontobel *et al.*, (2023) [79] found that first-parity sows and those with prolonged farrowing durations were more susceptible to diseases after farrowing. Additionally, the use of antibiotics during the gestation period was noted to impact the occurrence of postpartum diseases. The study also highlighted a 64% chance of constipation in the immediate days after postpartum. If constipation was present during late gestation, it resulted in increased farrowing duration and decreased sow appetite in the initial days postpartum. Tabeling *et al.*, (2003) [82] stated that fecal consistency in peri-partum sows significantly affects the health status of the mother post-partum. Therefore, it is advised to reduce the ration and fiber content in the diet in the days just prior to expected parturition. Pearodwong *et al.*, (2016) [61] identified a relationship between the constipation status of the animal just before and on the day of parturition with her farrowing performance. Sows with lower intestinal motility on the day of farrowing exhibited a higher incidence of fever and reduced appetite.

Peltoniemi *et al.*, (2016) [62] emphasized that postpartum complications such as foetal membrane retention, postpartum dysgalactia syndrome, heavy pre-weaning mortality, and reduced colostrum secretion are connected with the total farrowing duration. Kaiser *et al.*, (2018) [34] investigated metabolic factors affecting postpartum dysgalactia syndrome and observed a higher occurrence of diseases in sows with Body Condition Score (BCS) 3 compared to BCS 2. The rate and severity of PDS were also higher in cases where difficulty in farrowing occurred and when the duration of parturition was prolonged. The study further noted that litters from sows positive for post-parturient diseases exhibited less weight gain. Karst *et al.*, (2021) [35] conducted a study on the occurrence of Metritis-Mastitis-Agalactia (MMA) in pigs and pointed out that MMA is a significant and common threat in pig farming, adversely affecting both the longevity of the mother and the health status of the litter.

Hematological, biochemical and hormonal variations

Boulbria, *et al.*, (2021) [9] reported that during the gestation period, RBC count, PCV, MCV, WBC count, and copper concentration are lower, while Hb is lower in both gestation and lactation periods. They also found that MCH value is higher during pregnancy and lower during lactation, whereas zinc concentration is higher during gestation, and glucose level is higher during lactation. When animals experience stress, the utilization of body reserves increases, and in a sow's life, weaning (Campbell *et al.*, 2013) [10] is a period associated with high stress.

Verheyen *et al.*, (2007) [90] focused on serum biochemical changes in both gestating and lactating sows, suggesting that these parameters can serve as tools to evaluate the health status of the animals. However, they emphasized that considering parity and the stage of reproduction is essential for accurate interpretation. Rekiel *et al.*, (2011) [68] mentioned a significant difference in the levels of albumin, total protein, high-density lipids, BUN, and creatinine values during the last stages of lactation in sows. Bhattarai *et al.*, (2015) [8] stated that there is a positive correlation between the hematological status of the litter at weaning and the rate of body weight gain. An extra growth rate of 17.2 grams body weight is observed for each additional 10 grams of Hb/L, and this correlation is more evident during the initial period after weaning.

Litter-level reproductive performance indicators in pigs

Body weight of the piglets at birth and weaning

Magnaboscoa *et al.*, (2016) [47] state that piglets with a birth weight less than 1 kg will exhibit low reproductive performance, including an average litter size of less than 4.5 in their first parities and low longevity in the reproductive process. Tolosa *et al.*, (2021) [86] report that average daily gain in weight and body weight will be higher in piglets weaned on the 42nd day compared to those weaned on the 15th and 21st days. However, on a farm profit basis, weaning during the 21-28 day period is also recommendable. Jose, (2009) [32] states that the optimum weight of the piglet at the weaning age is around 7-8 kg in pigs, achievable at the 28th day after farrowing. If the weaning weight is less, there is an increased likelihood of reduced growth rates and mortality. Knecht *et al.*, (2015) [40] conclude that the season has a very high correlation with the weaning weight of piglets. These findings collectively underscore the critical importance of birth weight, weaning age, and environmental factors in determining the reproductive performance and growth outcomes of piglets.

Colostrum intake by the piglets

Colostrum consumption significantly benefits piglet performance and reduces mortality both in the short and long term. However, the production of colostrum by sows and the intake by piglets are not only limited but also exhibit considerable variability (Declerck *et al.*, 2017) [19]. A significant number of piglet deaths in the initial days post-birth can be attributed to their failure to consume adequate colostrum. Based on recent research, it's recommended that each piglet should ideally consume a minimum of 200 g of colostrum within the first 24 hours post-birth. This intake level not only reduces mortality risks before weaning but also imparts passive immunity and promotes modest weight gain. For optimal health and growth both before and after weaning, an intake closer to 250 g is advised. However, it's concerning that a considerable proportion of sows do not produce sufficient colostrum to meet the demands of their entire litter. To address this, strategies to enhance piglet colostrum intake should be explored. These include improving piglet suckling capabilities, minimizing birth weight discrepancies within litters, and boosting the colostrum production capacity of sows (Farmer and Edwards, 2022) [24].

Average daily gain in body weight

Collins *et al.*, (2017) [14]; Faccin, *et al.*, (2020) [22] state that the growth rate after weaning is positively related to the pre-weaning growth rate. Amdi *et al.*, (2013) [4] conducted a study on Landrace-Large white yorkshire crossbred animals and noted that the body condition of the sows significantly influences the rate of body growth of the litter. In this study, it was also reported that the rate of growth of piglets is higher for those from sows with 19mm backfat compared to piglets from sows with 12mm backfat. Kadirvel *et al.*, (2019) [33] found that, concerning Burmese pigs, the average rate of growth before the weaning period is nearly 149.56 grams per day, and the average rate of growth after weaning is around 297.25 grams per day. These findings highlight the importance of sow characteristics, particularly backfat, in influencing the growth rates of piglets during both pre-weaning and post-weaning periods.

Summary

Pigs are among the most prolific livestock species, with an average of 8-10 piglets per farrowing. Various factors influence their reproductive performance, including parity, housing and environmental conditions, nutrition, body condition of the animal etc. Despite these influences, reproductive traits have been found to be of low heritability. This means that genetic improvements targeting these traits have limited potential. Consequently, the best approach to maximizing production from a farm involves selecting superior animals for breeding and implementing optimal management practices. The reproductive longevity of individual animals within a breeding herd can vary and the duration an animal remains in the reproductive herd largely depends on its performance during previous farrowing. To make informed decisions about an animal's suitability for breeding, it's crucial to evaluate its performance from farrowing to weaning, both at the sow and litter levels. An animal should be excluded from the breeding program if it consistently produces litters with fewer total births, lower survival rates at birth, and reduced numbers at weaning. Additionally, indicators such as prolonged intervals from weaning to the next estrous cycle, elevated stillbirth rates, mummification rates, and high pre-weaning mortality rates suggest suboptimal reproductive performance. Furthermore, piglets exhibiting low birth and weaning weights, ADG, and inadequate colostrum intake should not be chosen for the next breeding herd selection.

CRediT authorship contribution statement

AA, SV: Writing- original draft preparation
AD, BM: Conceptualization, Writing- Review and editing

Declaration of competing interest

The authors declare that they have no conflict of interest.

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