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Piglet survival from birth to weaning: A narrative review of associated sow and piglet characteristics and environmental factors

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Abstract

Pre-weaning piglet mortality continues to pose a serious challenge to pig producers, with detrimental effects on animal health, welfare, performance, and overall farm success. This review examines the complex relationship between the sow and piglet characteristics and the environment that affects piglet pre-weaning survival. Due to the interrelated nature of the challenge, it is key to consider all factors when designing genetic selection and management programs. There are multiple parameters related to the sow, such as parity, body condition, maternal behavior, back-fat thickness, litter size, farrowing duration, nutritional and health status. Whereas for the piglet, the associated parameters to pre-weaning survival include birth weight and order, ability to access colostrum, sex, health, and disease resistance, blood glucose concentrations and body temperature. While large litters are a genetic option for economic gain, they are also associated with reduced survival rates attributed to higher variability in birth weight within a litter. The housing environment and management interventions contribute significantly to piglet survival rates. Because piglet survival is a complex multifactorial trait, this review highlights the necessity of an inclusive approach to combating piglet survival. Improving the survival of piglets through an integrated strategy of genetic selection, optimal environment, focused nutrition, and good management is a key to providing robust piglets that can grow and perform well throughout their lifetime. Overall, any piglet survival improvement that is to be sustainable requires the right balance of sow and piglet characteristics to optimise both production efficiency and animal welfare. Rather, the piglet survival is also important for the efficiency of production and the broader sustainable development goals (SDGs), including SDG 1: poverty reduction, SDG 2: food security, and SDG 12: responsible consumption and production.

1. Introduction

To cater for the increasing global demand for meat, intensive animal production systems have been developed. Globally, pig (*Sus domesticus*) production is one of the sectors where intensive farming practices are utilized (Maes et al. 2020; Matukane et al. 2024). Pig production plays a crucial role in addressing the escalating global demand for high-quality animal protein (Mun et al. 2023; Wang and Li 2024). However, pig production faces several critical challenges, including outbreaks of diseases such as African swine fever, high piglet mortality, low reproductive efficiency, and the rising cost of feed (Osei and Adu 2015). One of the important breeding objectives in pig dam-line production is improving litter size, as it directly determines the number of piglets born (Dekkers et al. 2011; Franczak et al. 2017), and it influences the profitability of the farming business. Since the 1990s, litter size trait has substantially increased (Dekkers et al. 2011). Improvements within the pork industry have yielded numerous advantages for farmers, including improved feed efficiency, greater lean gain, higher farrowing rates per year, increased piglets weaned per sow per year, and reduced age at slaughter (Shurson and Kerr 2023).

Advancements in pig production in developing countries have been largely driven by using exotic breeds and crossbreeding between indigenous and exotic pigs (Kadirvel et al. 2023). However, due to the negative genetic association between litter size and piglet mortality, breeding goals should focus on characteristics related to piglet survival along with the overall litter size (Buthelezi et al. 2024a, 2024b). Maternal behavior is highly linked to piglet survival, as sows with aggressive behavior sometimes accidentally crush and overlie their piglets during nursing (Girardie et al. 2023). Low reproductive efficiency remains a major reason for sow culling, which accounts for approximately 30% of culling. Breeding programmes therefore aim to improve the genetic potential of sows for higher productivity and to maximise the number of healthy piglets successfully weaned per litter (Blavi et al. 2021). High piglet mortality rates before weaning pose a substantial challenge in pig farming (Buthelezi et al. 2024a), and it results from complex interactions between the sow, piglet, environment, and management practices, ultimately impacting sow productivity and causing considerable financial losses (Madeira-Pacheco et al. 2024). Therefore, recognising the aspects that affect piglet performance before weaning is essential for improving the health and well-being of animals, minimizing losses, and boosting farm profitability (Buthelezi et al. 2024a, 2024b).

Knowledge of pre-weaning characteristics that influence piglet survival is inadequate. Therefore, this narrative review aims to synthesize recent and available literature concerning sow and piglet characteristics, as well as the environmental and management factors associated with pre-weaning piglet survival. Given that this review is intended to improve piglet survival rates, it aligns with Sustainable Development Goals (SDGs):

(i) SDG1 (No Poverty): The piglet survival, which is a focus of this review, is a crucial variable in the economic sustainability of pig farming and food security, especially among low-income communities.

(ii) SDG 2 (Food Security): Improving pre-weaning piglet survival will lead to increased efficiency in pork production.

(iii) SDG 12 (Responsible Consumption and Production): The improvement of the pre-weaning piglet survival will ultimately result in fewer resources, such as feed, water and energy, being wasted on animals that do not reach market.

Therefore, this narrative review identifies important risk and protective measures for an enhanced pre-weaning piglet survival, providing a comprehensive overview of the relevant literature. The scope covers research that investigated the relationship between pre-weaning piglet survival and sow, piglet and environmental factors.

2. Materials and Methods

A narrative approach was used to synthesize findings from relevant studies published in peer-reviewed journals. An electronic search strategy involved a systematic search in electronic databases (Google Scholar, PubMed, Science Direct, and SciELO) using relevant keywords such as, "piglet survival," "pre-weaning mortality," "sow traits," and "piglet traits". During the research, only articles that investigated the association between sow and piglet characteristics, environmental conditions, management factors, and the pre-weaning survival rate were selected. The review critically evaluated the evidence and provided a synthesis of the key findings by highlighting areas of consensus and disagreement in the literature. Fig. 1 summarises the sow, piglet, and environmental factors associated with pre-weaning piglets survival.

Fig. 1. *Sow and piglet characteristics and environmental factors associated with pre-weaning piglet survival*

3. Sow characteristics influencing piglet survival

Sow characteristics like parity (Klimas et al. 2020; Corrales-Hernández et al. 2025), maternal care and capacity (Ocepek and Andersen 2017; Rosvold et al. 2019), udder structure and function, and nutritional status strongly impact the survival of piglets. Hence, understanding sow-related traits is important for the development of successful and implementable management tools to enhance piglet survival and increase the economic efficiency of pig production. A summary of sow traits affecting piglet survival and their explanation is shown in Table 1.

Table 1. Summary of sow characteristics influencing piglet survival and their mechanisms

Sow characteristics	Influence on piglet survival	Mechanism	References
Parity	Sows in higher parities (5-8) are associated with higher stillborn rates than sows in lower parities (1-4).	Sows in higher parities farrow piglets with weight variation within litters, and a long farrowing duration. Sows in lower parities farrow piglets of uniform weight.	(Zindove et al. 2021; Buthelezi et al. 2024a, 2024b)
Body condition and depth	Excessive body condition is linked to high stillborn rates, whereas low body condition and depth are associated with lower chances of survival	Excessive body condition leads to prolonged parturition, which can cause high stillborn rates. Low body condition and depth result in negative energy balance, often leading to reduced chances of survival after birth.	(Decaluwé et al. 2013; Muro et al. 2023; Monteiro et al. 2025)
Large litter size and birth weight variation	Large litter sizes are associated with high pre-weaning mortality rates.	Higher litter sizes lead to lower birth weight and high weight variation at birth, intrauterine growth restriction and inadequate colostrum intake, which adversely affect piglets' survival.	(Oliviero et al. 2019; Zindove et al. 2021; Buthelezi et al. 2024a, 2024b)
Nutrition	Adequate nutrition is associated with high survival rates and vice-versa.	Adequate nutrition leads to good embryo development, shorter farrowing duration, and sufficient colostrum production, which are crucial for greater survival rates.	(Oliviero et al. 2019; Langendijk 2021; Carnevale et al. 2023)
Farrowing duration	Long farrowing duration is associated with low chances of survival	Long farrowing duration leads to hypoxia in piglets, and may cause stillbirths and stunted growth, which can lead to reduced survival after birth.	(Peltoniemi et al. 2020; Rutherford 2021)
Maternal behavior and ability	Good maternal behavior and ability are linked with high chances of survival and vice-versa.	Sows with maternal instincts have careful posture changes, efficient nursing, and nest building, leading to fewer crushing incidences and greater piglets' survival.	(Pedersen et al. 2011; Blavi et al. 2021; Zhang et al. 2021)
Number of functional teats	A sufficient number of functional teats is associated with the high survival rates and vice-versa	Sows with a sufficient number of functional teats provide adequate access to colostrum for all piglets, therefore improving the survival rate.	(Balzani et al. 2015; Balzani et al. 2016; Dominguez et al. 2020)
Health status and diseases (Postpartum infections)	Sows of good health status and free from post-partum diseases often have improved piglet survival rates.	Sows with good health and free from postpartum diseases can feed properly and have unimpaired immunity that could be passed on to piglets and can produce sufficient colostrum for piglets. Whereas mastitis infection in sows disrupts milk production and nutrient uptake, resulting in low-quality milk, leading to impaired piglets' growth and immunity.	(Gebhardt et al. 2020; Blavi et al. 2021)

3.1. Parity

Though survival of piglets is a complex issue, sow parity is a major factor prior to weaning. Parity is closely linked with the physiological adaptations that are mainly related to maturation and functionality of the reproductive system (Engblom et al. 2007; Klimas et al. 2020). These adaptations affect the sow's ability to both promote fetal development as well as to provide care post-parturition and thus affect piglet survival. Changes in sow physiology with increasing parity number alter foetal development in utero before birth (Motaung et al. 2024). Typically, sows in their first and second parity produce fewer piglets compared to those in middle (parities 3–5) and older parities (parities 6–8) (Kilmas et al. 2020). Although gilts bred at a younger age may have smaller litters during early parities, they often have longer productive lifespans than those bred at an older age. As a result, they will produce healthy litters over time with higher chances of survival (Malanda et al. 2019). Engblom et al (2007) found a positive correlation between increasing parity and the number of piglets born alive. Therefore, extending the productive lifespan of sows beyond the third parity contributes substantially to economic value through their reproductive output (Engblom et al. 2007; Corrales-Hernández et al. 2025). However, piglets born alive from first, third, and fifth parity sows tend to have lower birth weights (Buthelezi et al. 2024a). Lavery et al. (2019) and Buthelezi et al. (2024a) reported that first and second-parity sows show smaller differences in within-litter birth weight, whereas older sows exhibited greater variation, likely due to higher ovulation rates. Birth weight variation has been inversely linked to the pre-weaning survival rate of piglets (Buthelezi et al. 2024a). Higher litter size could result in intra-uterine crowding, which influences the development of the placenta and impairs piglet survival and growth (Ward et al. 2020; Zindove et al. 2021; Buthelezi et al. 2024a, 2024b). In contrast, small litter size in the early parities produces piglets with high weaning weight and survival probability.

Prolificacy and stillbirth rates of multiparous sows are usually higher than those of primiparous ones (Motaung et al. 2024; Buthelezi et al. 2024a), likely due to the additional physiological stress of carrying larger litters, which might compromise the oxygen and nutrient supply of individual embryos, increasing the predisposition of the foetuses to stillbirth (Van den Bosch et al. 2023). The second and third parity sows experience less piglet loss before weaning, as a result of improvement in maternal experience and behavior from early- to mid-parity sows (Lavery et al. 2019; Corrales-Hernandez et al. 2025). On the other hand, gilts and primiparous sows might not possess the required experience and agility to nurse and care for piglets optimally, such as refusal to nurse or poor nest building (Engblom et al. 2007), which contributes to higher piglet mortality even in small litter sizes. Klimas et al. (2020) compared parity effects between breeds and reported that litter size increased up to the fifth parity in Large White and Landrace sows, while pre-weaning survival declined in later-parity litters from sows beyond sixth parity. This decrease may be associated with declining sow condition, milk production, or maternal ability at an older age, resulting in lower piglet care and survival (Vargovic et al. 2022). Therefore, although selection for parity initially results in higher pre-weaning survival but further higher parities result in low maternal ability and higher piglet losses (Muro et al. 2023).

3.2 Body condition and back-fat depth

Nutrient allocation and dietary management throughout gestation significantly influence the body condition of the sow, which in turn affects the reproductive outcomes such as piglet weight at weaning, birth weight, and overall vitality (Langendijk et al. 2023). To sustain exceptional litter performance in subsequent farrowing periods, it is essential to maintain optimal sow condition throughout lactation and gestation (Lavery et al. 2019; Blavi et al. 2021; Motaung et al. 2024). The body condition and backfat thickness are significant in influencing the number of born alive piglets and the overall reproductive efficiency in highly productive sows (Lavery et al. 2019; Motaung et al. 2024). Sows with high late gestation body weight and backfat farrows larger litters and an increased number of piglets born alive (Lavery et al. 2019; Matukane et al. 2024). However, fat sows have long farrowing durations coupled with high stillbirth rates (Muro et al. 2023). This validates the adverse effect of obesity on reproductive efficiency. Furthermore, increased mortality risk and reduced feed intake are observed in sows with poor body condition (Monteiro et al. 2025). Sows with greater backfat thickness are viewed as having better body condition and energy status (Mun et al. 2023), resulting in greater pre-weaning piglet survival rates (Motaung et al. 2024). Nevertheless, excessive backfat at birth can lead to dystocia and increased culling rates (Ferrari et al. 2014) and thinner backfat sows are more susceptible to negative energy balance in the postpartum period with reduced lactation (Motaung et al. 2024; Monteiro et al. 2025), potentially leading to a lower survival rate of piglets.

3.3. Litter size and within-litter weight variation

Litter size is of great concern in the pig industry, as it influences the performance of sows and economic return (Zindove et al. 2021; Buthelezi et al. 2024a, 2024b). Advances in pig production have resulted in improved litter sizes (10-16 piglets) driven by better animal husbandry techniques, nutrition, and selective breeding, with an annual production of 25 - 30 pigs per sow. This marks an increase of three piglets over the past 40 years (Rutherford et al. 2013). However, larger litters are associated with lower birth weight and greater variation in birth weight among littermates (Zindove et al. 2021; Buthelezi et al. 2024a). Common issues with large litters are newborn piglets with intrauterine growth restriction (IUGR), prolonged farrowing duration, competition for teats, insufficient colostrum intake, and higher pre-weaning mortality rates (Oliviero et al. 2019; Buthelezi et al. 2024a).

In litters with significant birth weight variation, the smallest piglets often struggle to access the best teats, resulting in lower consumption of colostrum and milk, and consequently, compromised immune function and nutritional status (Oliviero et al. 2019). Low mean birth weight is associated with slow growth rates and low pre-weaning, growing, and finishing stage survival (Zindove et al. 2013; Buthelezi et al. 2024a, 2024b). Minimizing birth weight variation within litters can improve the survival of piglets (Buthelezi et al. 2024b). Therefore, achieving a balance between litter size and uniformity is crucial for maximising piglet survival in pig production (Zindove et al. 2021; Buthelezi et al. 2024a, 2024b).

3.4 Nutritional status

Nutrition during gestation

The nutritional quantity and quality of feed provided to the sows are one of the critical determinants of foetal growth, placental function adequacy, and piglet viability (Hasan et al. 2019). Sows and foetal litters have common basic metabolic requirements that must be met during pregnancy (De la Cruz-Cruz et al. 2024). Diets rich in fibre, protein, fat, and carbohydrates are often given to sows while gestating so that the foetuses can obtain all the energy they require for their growth and development, and the body maintains the sow (Hansen et al. 2012). Phase feeding during gestation and parity-specific barrier feeding during lactation increase lifetime fitness and offspring survival (Kim et al. 2015). Inadequate nutrition during gestation can also impair placental development and function, which affects nutrient and oxygen transfer across the placenta, resulting in inhibited foetal growth, low birth weight, and a greater rate of stillborn pigs (Langendijk 2021). Therefore, appropriate foetal feeding nutrition at all stages of gestation is crucial for the optimization of piglet vitality and survival (Hansen et al. 2012).

Nutrition during lactation

Energy of the sow at farrowing influences the farrowing duration and pre-weaning piglet survival (Carnevale et al. 2023). Fasting sows for more than 6 hours prolongs farrowing, and consequently, results in a greater number of stillborn pigs and the need for intervention (Staarvik et al. 2019). Moreover, optimal levels of glucose in the blood must be maintained to facilitate efficient uterine contractions and shorter labor (Staarvik et al. 2019). Underfed sows at farrowing often provide reduced colostrum quantity, which plays an important role in piglets' passive immunity during the first 3-4 weeks after birth (Oliviero et al. 2019). For piglets to survive and grow after birth, nutritional regimens that promote colostrum and milk production are crucial (Hansen et al. 2012).

3.5. Farrowing duration

The use of modern selection approaches for large litters resulted in a prolonged farrowing duration from around 2 h with 12 piglets to over 6 h with 19 piglets (Peltoniemi et al. 2020). Consequently, this results in an increase in the stillbirth rate and the sows' stress, postpartum disorders, and reduced fertility in the subsequent reproduction cycle (Devillers et al. 2011; Ju et al. 2022). Piglets born late during extended farrowing are more likely to experience hypoxic events, which can include the breaking of the umbilical cord, decreased blood flow to the fetus, or intensified uterine contractions that decrease the amount of oxygen in the brain and other vital organs (Alonso-Spilsbury et al. 2005; Langendijk and Plush 2019). Hypoxic piglets frequently display reduced suckling strength, decreased colostrum intake, poor thermoregulation and increased pre-weaning mortality (Langendijk and Plush 2019). Therefore, timely intervention in sows exceeding 240 minutes of duration is crucial to minimize mortality.

3.6. Maternal behavior and maternal ability

The maternal behavior has a major impact on the survival of piglets, especially in the first 24 h after birth, when the risk of mortality is the highest (Ocepek and Andersen 2017). Behaviors such as lying with teats exposed, nest-building, and active response to piglet distress reduce early mortality due to starvation and crushing (Pedersen et al. 2011; Blavi et al. 2021). The use of the farrowing crates is common and has limited crushing by constraining the movement of the sows, however, it restricts natural sow behaviors and may increase stress (Rosvold et al. 2019). Contrary to this, a study by Portele et al (2019) indicated that free-farrowing sows display better maternal behavior and lower piglet mortality. Nevertheless, in confinement, sows' responsiveness to trapped piglets remains limited, and high teat competition in fostered litters could lower suckling success (Singh et al. 2017; Zhang et al. 2021). Despite attempts to curb piglet crushing, it still contributes a high proportion towards pre-weaning mortality, and it strongly depends on litter size, birthweight, sow parity, and environmental stress (Buthelezi et al. 2024b). Older and fat sows, anxiety and fear, and inexperience elevate the risk of sow crushing (Thompson et al. 2019).

3.7 Sow genetics

Genetic variability in survival traits paves the way for selection against the sows not well adapted to the environment (Knol et al. 2022). Phenotypic variation is not useful for selecting breeding candidates, as natural selection has already eliminated the unfavorable variants. Genomic analysis, which identifies the genes linked to piglet survival, proves useful in such instances. Udder morphology, placental characteristics and the quantity and quality of milk produced are the sow's genetic factors that will be addressed in this section.

Udder morphology

The morphology of the udder in the sow, determined by the breed, parity, teat functionality, and teat position, is a determining factor of piglet access to milk and subsequent survival (Balzani et al. 2016; Dominguez et al. 2020). Sows of medium size have smaller teats with greater and desired uniformity than large-sized sows (Balzani et al. 2016). Primiparous sows possess smaller teats and a reduced inter-teat distance in comparison with multiparous sows, with restricted milk production possibly resulting in risk of piglet starvation (Dominguez et al. 2020). Genetic selection could improve teat functionality, which varies among breeds and parities and is characterized by teat size and glandular development (Earnhardt-San et al. 2023). Access to milk is also influenced by teat position because the posterior teats are longer and further apart, and piglets prefer them (Dominguez et al. 2020). A study by Balzani et al. (2016) reported that most piglets initially suckled from previously used posterior teats, although late-born piglets often preferred anterior teats. While a greater inter-teat distance can reduce competition and improve suckling efficiency, inadequate sternal support on anterior or poorly developed teats may disadvantage lighter piglets. In older sows, increased teat height and reduced prominence may disadvantage lighter piglets (Vasdal and Andersen 2012). Udder morphology differs with parity. First- and second-parity sows typically have smaller teats and less-developed udders compared with older multiparous sows (Balzani et al. 2016). However, teats in older sows become higher and less prominent, which may impair access, increase competition, and elevate piglet mortality (Vasdal and Andersen 2012). Therefore, timely teat attachment is particularly crucial in large litters, as delayed suckling reduces colostrum intake and causes higher mortality (Earnhardt-San et al. 2023).

Placental characteristics

The size and weight of the placenta vary between different breeds of sows and have a great influence on piglet survival. The placenta is the primary organ of the foetus for nutrient and metabolite exchange essential for normal foetal growth (Vernunft et al. 2018). An inefficient placenta development in early gestation could lead to decreased foetal survival and growth, reflecting on litter performance (Vonnahme 2018). On the other hand, maximum utilisation of uterine capacity and well-developed and highly efficient placentas are important factors to improve sow fecundity and litter performance (Geijer-Simpson 2022). It has been demonstrated that a greater area and weight of the placenta are associated with a higher birthweight of the piglet and better survival until weaning (Tucker et al. 2021; Langendijk et al. 2023). Vernunft et al. (2018) demonstrated that litter size is negatively associated with placental weight in total litter, as placental efficiency does not affect the level of fertility of the sows.

Quality and quantity of milk production

Adequate mammary gland development is also necessary for effective colostrum production, which directly impacts piglet survival through passive immunity and nutrient transfer (Corrales-Hernandez et al. 2025). Sufficient access to sow milk and colostrum is essential for the survival of piglets from birth to weaning as it fulfils their high energy demands needed for their daily physical activity and thermoregulation (Muns et al. 2016). Newborn piglets require a minimum of 200 g high-quality colostrum with a concentration of > 50 mg IgG/ml porcine colostrum to achieve adequate passive immunity transfer, thereby improving their survival (Björkman and Grahofer 2021). However, there is a high variation in colostrum produced by sows, which is on average approximately 3.5 kg (between 1.5 and 6.0 kg), but some sows may not produce enough colostrum to feed all piglets, especially low birth weight piglets, leading to pre-weaning mortality (Corrales-Hernandez et al. 2025). Mammary gland development and colostrum production are influenced by sow breed and diet during late gestation (Zou et al. 2020). For instance, hyperprolific sows supplemented with beta-glucan increased colostrum immunoglobulins, enhancing piglet livability and growth performance (Dos Santos et al. 2023). Some breeds of pigs, Large White, show very good milk performance, so choosing breeds or lines with genetics of good maternal ability is expected to enhance the milk performance and survival of piglets (Knol et al. 2022).

3.8 Health status and diseases

High sow morbidity, mortality and decreased performance are significant contributors to economic losses from pig production worldwide (Maes et al. 2020). A healthy sow is the sow with no disease in the main body systems (respiratory, digestive, locomotion) of primary physiology (WOAH 2019). Underperformance is commonly associated with poor nutrition, housing environment, stockmanship, environmental stress and pathogen exposure (Jayaraman and Nyachoti 2017). Notwithstanding biosecurity, vaccination, and antimicrobial interventions, diseases like Porcine Reproductive and Respiratory Syndrome Virus (PRRSV) and Porcine Circovirus Type 2 (PCV), influenza viruses (IV), *Salmonella* spp., and *Escherichia coli* continue to cause high morbidity and mortality on farms (van der Waal and Deen, 2018).

Sow immunity and body condition are important factors for litter health, and immune-deficient or diseased sows pass less passive immunity, which results in a higher pre-weaning mortality (Le Dividich et al. 2017). Milk yield reduction caused by disruption of mammary integrity also has negative consequences, such that piglets cannot properly suckle the mother's teats because of low milk yield, which can lead to growth alteration and increased losses (Blavi et al. 2021). Effective management of sow health and immunity is thus of paramount importance to improve piglet survival and health, which ultimately optimizes efficiency of production in commercial pig systems.

3.9 Birth weight

It is generally recognised that the body mass of piglets at birth is a vital measurement for their survival. There is a significant correlation between the weight of piglets and pre-weaning mortality (Buthelezi et al. 2024a). Piglets with low birth weight grow at a slower rate, accumulate more body fat, and are more likely not to survive from birth to weaning (Cabrera et al. 2012). Low birth weight in piglets results consequently, when the number of foetuses exceeds the capacity of the uterus. This phenomenon leads to intrauterine growth restriction (IUGR), which adversely affects the pre-weaning piglet survival (Huting 2020). Hyper-prolific sows have an increased ovulation rate, which consequently leads to foetuses competing for a supply of oxygen and nutrients, ultimately resulting to piglets with lower birth weight and greater within-litter variation (Beaulieu et al. 2010). Piglets born heavier have greater weight gain during lactation due to their ability to stimulate and nurse from the most productive teats, which triggers increased milk production and enables greater nutrient intake, unlike lighter piglets (Berard et al. 2010). Piglets born weighing under 1 kg at birth have a reduced likelihood of surviving until weaning (Fix et al. 2010). Additionally, piglets with low birth weights show changes in organ development and digestive function, particularly affecting enzyme secretion and nutrient absorption (Lanferdinia et al. 2018). The development of organs in piglets with low birth weight may be impacted due to the redistribution of the flow of blood to safeguard the brain (Tan et al. 2022). Consequently, due to higher mortality, morbidity, and inferior development of low body weight piglets, it is not worthwhile to keep these piglets (Huting 2020).

4. Piglet characteristics influencing survival

4.1 Birth order

In piglets, a higher birth sequence is linked to lower birth weight and greater mortality before weaning (Slegers et al. 2021). This association has become increasingly relevant due to the prevalence of hyper-prolific sows, which produce large litters and thereby increase the importance of birth order as a contributing factor (Uddin et al. 2022). There is a positive correlation between birth weight and birth order, with heavier piglets typically being delivered earlier (Camp Montoro et al. 2020). Piglets born earlier in the sequence exhibit higher vitality and consume greater quantities of colostrum than their later-born counterparts (Slegers et al. 2021). Therefore, late-born piglets are at a disadvantage in acquiring passive immunity compared to those born earlier, largely due to two contributing factors (Le Dividich et al. 2017; Matukane et al. 2025). Firstly, by the time the last piglets reach the udder, the anterior teats are already occupied, and colostrum quality has begun to deteriorate. Secondly, oxygen-deprived piglets may struggle to navigate to the udder due to asphyxia at birth (Diehl et al. 2022). Elevated umbilical cord lactate in last-born piglets is evident due to a longer duration in the uterine horn and parturition canal, resulting in more severe hypoxia, lower heart rates, and longer asphyxia (Uddin et al. 2022). The final piglets in a litter endure the most intense part of the birthing process, facing stronger and more prolonged uterine contractions, which hinder blood flow and reduce oxygen supply to the fetus, making birth particularly stressful for these piglets (Alonso-Spilsbury et al. 2005). Additionally, the likelihood of umbilical cord rupture increases with birth order, which can result in lasting neurological damage (Rootwelt et al. 2012).

4.2 Colostrum intake

Colostrum is a highly nutritious secretion produced by the mammary glands of sows during the first 24 to 48 hours after parturition, prior to the onset of regular milk production (Matukane et al. 2025). This secretion is crucial for neonates as it is rich in nutrients such as proteins and minerals and energy, which facilitates pre-weaning growth of neonates and satisfies their thermoregulation needs. Furthermore, colostrum is involved in passive immunity as it delivers maternal antibodies that aid piglets' resilience against infections during the neonatal phase, as their immune system is not fully developed (Pluske et al. 2018; Matukane et al. 2025). Piglets that do not receive sufficient colostrum shortly after birth are more vulnerable to infections and mortality (Rutherford et al. 2013). Inadequate colostrum intake is a significant contributor to pre-weaning mortality and reduced growth, especially in underweight piglets (Declerck et al. 2016). Since colostrum production is not affected by the size of the litter (KilBride et al. 2010), the management of colostrum should focus on low-birth-weight piglets to enhance vitality and survival (Declerck et al. 2017).

4.3 Sex of the piglets

Sex influences piglet pre-weaning growth and survival (Lorente-Pozo et al. 2018). Male piglets are more impacted by morbidity and mortality relative to female littermates due to physiological, environmental, and social circumstances (Baxter and Edwards 2018). They are more at risk of preterm delivery, respiratory diseases, weakened immunity, and poor vaccine response (Chu Thinh et al. 2022). Male neonates are usually heavier at birth and have greater metabolic demands and an increased neurological weakness, which leads to increased piglet crush, malnourishment, and hypothermia compared to their female contemporary littermates (Baxter et al. 2012). These sex dimorphisms from a physiological aspect demonstrate the necessity of incorporating sex into the formulation of neonatal strategies to help the survival of male piglets.

4.4 Piglet health and disease resistance

The causes and mechanisms resulting in piglet mortalities and survival depend on several interlinked factors (Heuß et al. 2019). Though immune competency and general health traits have a vital impact on piglet survival, they are rarely given priority in breeding programmes (Clapperton et al. 2008), which affects the survival of piglets. The passive immunity derived from the intake of colostrum is the major defense against neonatal infections (Le Dividich et al. 2017; Matukane et al. 2025). A successful disease resistance relies on preventing the entry of infections as well as limiting their spread within the host (Bai and Plastow 2022). A key primary resistance mechanism is the lack of specific receptors on host tissues or cells that are needed for pathogen adhesion, colonisation, and toxin formation (Plastow 2016). Newborn piglets show rapid establishment of gut microbiota that aid in digestion, immune maturation, and protection against pathogens, whereas pathogenic bacteria, such as *E. coli*, Salmonella and Clostridia, cause enteric disturbances (Gresse et al. 2017). Lameness undeniably worsens survival through decreased mobility and a higher risk of being crushed and it is more prevalent in piglets of gilts and with shorter lactation sows (Oliviero et al. 2019). Hygienic management and sanitary practices are essential to support growth performance and reduce disease in piglets. In commercial settings, inadequate sanitation correlates with reduced growth, chronic immune activation, and systemic inflammation, which divert nutrients from growth to immune function, increasing susceptibility to disease and compromising survival during the critical pre-weaning period (Pluske et al. 2018). At the same time, the use of antimicrobials in pig farming is excessive, thus leading to the spread of antimicrobial resistance and increasing the probability of zoonotic transmission, which is a threat to both animal and human health (Zhang et al. 2024). Therefore, the ability of probiotics to normalize gut microbiota and improve intestinal barrier function represents a much safer solution than antibiotics to reduce pre-weaning mortality in pigs (Gresse et al. 2017).

4.5 Physiological indicators at birth

Blood glucose levels

Blood glucose level is one of the most widely investigated parameters of neonatal vitality and postnatal survival in piglets (Vanden Hole et al. 2019). Blood glucose levels are positively associated with both survival and growth performances in neonatal piglets (Staarvik et al. 2019). Breeding aimed at producing larger litters has intensified the inherent energy deficit observed at birth (Rutherford et al. 2013). Newborn piglets are born with limited glycogen reserves, which provide the energy to maintain metabolic activity for approximately 16 h only (Theil et al. 2022). Consequently, piglets are born at an energy deficit, and to meet their energy needs and passive protection, they rely on immediate suckling of colostrum (Theil et al. 2014). If colostrum uptake is limited, blood glucose will decrease to severely hypoglycaemic concentrations (<2.2 mmol/L−1) within 24 to 36 h after birth and produce apathy and weakness; and in severe cases, coma or death (Giouleka et al. 2023). Lethargic piglets are at higher risk of being suffocated by the sow, further elevating pre-weaning mortality (Edwards and Baxter 2015).

Piglets with blood glucose below or equal to 24 mg/dL during the lactation stage had lower growth performance than those with higher glucose concentration (Thongsong et al. 2019). Low colostrum intake predisposes piglets to hypoglycaemia and an impaired immune system. Suckling piglets with low birth weight have high energy requirements per unit body weight due to their large surface area to volume ratio (Vodolazska et al. 2023). The surface area to volume ratio is directly related to heat loss to the external environment. A neonatal piglet does not have enough body fat and brown adipose tissue for non-shivering thermogenesis (Sjaastad et al. 2010). Consequently, such piglets are highly vulnerable to cold stress and require immediate energy to maintain homeothermy for survival (Edwards and Baxter 2015).

Body temperature

The thermal environment of neonatal piglets has been critical to early-life survival and productivity. Rectal temperature is a valuable factor in determining thermal comfort or stress in the neonatal piglet (Rashamol et al. 2020). Newborn piglets face a rapid decrease in body temperature after birth, mainly due to imbibition of amniotic fluid and contact with a cooler environment (Bienboire-Frosini et al. 2023). This first decline, which occurs 15-90 minutes post-partum, may pose a danger to the newborn's life. The newborn piglet is a thermally unprotected animal because of their tiny body insulation, limited body fat storage, and embryonic thermal control regulatory systems (Van de Pol et al. 2021b).

While sows' farrowing ambient temperature is typically adjusted to within the thermoneutral segment of 15°C to 19°C, which leads to piglet thermal discomfort because their optimal ambient temperature range is 32°C-35°C (Stinn and Xin 2014). For this reason, heating to avoid chilling and reduce mortality is essential (Tucker et al. 2023). Common interventions include the use of warming boxes to confine piglets under heat sources and drying piglets at birth to minimize evaporative heat loss (Van de Pol et al. 2020). Piglets with low birth weight are particularly vulnerable due to their large surface area relative to their body volume, which accelerates heat loss (Van de Pol et al. 2021a) and could lead to reduced neonatal survival. However, the likelihood of hypothermia reduces as the piglets develop more body fat and thermogenetic capacity during their period of lactation. Therefore, early interventions at birth are still crucial in improving neonatal survival and developmental outcomes (Ramirez et al. 2022).

5. Environmental factors affecting piglet survival

5.1 Housing conditions

The housing environment plays a vital role in the development and survival of young pigs in modern, intensive production systems (Ramirez et al. 2022). According to Ludwiczak et al. (2021), pigs should be housed in an environment that will enable them to express species-specific behavior such as rooting, exploration, and an exposed environment to physical activity, required for their survival. These behaviors are essential for normal physiological and psychological development, reducing stress and improving the survival of piglets. Group housing is encouraged to mitigate aggressive tendencies and promote social behavior, which in turn can improve welfare, survival and reduce injuries associated with social stress. However, conventional intensive systems often limit these opportunities, resulting in various stressors related to behavioral restriction that may compromise piglet survivability and increase susceptibility to diseases (Giuliotti et al. 2019). An optimal housing environment should prevent injuries, illness, hunger, thirst, discomfort, and exposure to unsuitable climatic conditions to improve piglet survival rates (Ludwiczak et al. 2021). Although complete elimination of stressors in livestock systems is challenging, environmental enrichment strategies such as expanded living space and access to rooting materials enhance animal welfare and overall health by promoting natural behavior, reducing stress-related immune suppression, and improving growth rates can enhance the survival of piglets (Godyn et al. 2019).

Neonatal piglets are particularly vulnerable to hypothermia due to their limited ability to regulate body temperature and low energy reserves. Therefore, establishing a suitable microclimate within farrowing units is essential to reduce pre-weaning mortality by providing localised warmth to piglets. This targeted heating approach is more energy-efficient and mitigates heat stress in sows compared to heating entire farrowing rooms (Ramirez et al. 2022). Flooring material affects thermal balance as well; metal flooring was found to decrease rectal temperature more rapidly than concrete flooring due to greater thermal conduction and low insulating capacity (Pedersen et al. 2016). Expanded metal flooring with a plastic-coated surface improves piglet performance more than concrete slats, possibly by increasing hygiene and thermal comfort (Andersen and Pedersen 2015). Straw bedding is more effective in supporting rectal temperature in undried piglets than radiant heating plates, as straw insulates against heat loss and offers a dry and comfortable lying surface, thus decreasing piglet mortality (Pedersen et al. 2016).

Farrowing pens were developed to increase the survival of piglets and facilitate human management by controlling the sow movements to prevent piglet crushing (Ceballos et al. 2021). However, sow confinement in farrowing crates has been demonstrated to induce higher levels of stress with higher heart rate and cortisol release (Goumon et al. 2022) and may also be associated with increased stillbirth rates (Lagoda et al. 2022). Such crates are highly restrictive, most notably inhibiting the ability of the sow to stretch or turn around, and there is considerable concern about the welfare of animals in such crates. In response to this, pen systems are prohibited in several countries, such as Finland, Norway, Switzerland and Sweden, as well as a ban on new installations in Sweden and Russia has been imposed (Einarsson et al. 2014; Peltoniemi et al. 2021). Despite these improvements, Dumniem et al (2023) reported that pre-weaning piglet mortality and crushing rates are higher in free-farrowing pens compared to conventional crate systems. The commercialisation and intensification of pig production have led to the practice of high stocking densities, aimed at improving space utilisation within pens and enhancing overall management efficiency and profitability (Pedersen 2018). However, stocking density is another critical factor affecting thermal comfort and the survival of piglets. Temperature and humidity rise with increasing stocking density, ventilation efficiency falls, and carbon dioxide (CO_2), carbon monoxide (CO), ammonia (NH_3), and hydrogen sulfide (H_2S) buildup occur, negatively impacting respiratory and immune systems and potentially impacting pre-weaning mortality (Marszałek et al. 2018).

5.2 Temperature and humidity

Ambient climate is a key environmental element that directly influences piglet health, welfare, survival, and overall productivity (Hörtenhuber et al. 2020). The pig farrowing facilities must meet the thermal needs of both nursing sows and their neonates, which are different yet complementary (Baxter and Edwards 2021). These conflicting thermal requirements make environmental control in farrowing facilities very complex. Newborn piglets are particularly vulnerable to chilling during the first two hours post-partum, and interventions to minimize the severity and duration of an early drop in body temperature (Ramirez et al. 2022). The thermoneutral zone for piglets after birth is 34 to 35°C (Krommweh et al. 2014), whereas for the nursing sows it is around 18°C (Milan et al. 2019). Huddling is a thermoregulatory behavior that minimizes heat loss through pig-to-pig contact (Robbins et al. 2021). Excessive stocking densities may promote aggressive interactions between piglets (Laves et al. 2021), which could result in physical injuries, stress and health-related issues. Furthermore, climatic variations determined by the geographical location and production system design complicate temperature management at the piglet level even more (Tucker et al. 2021).

Standard farrowing crates normally include a designated creep area with supplemental heat sources such as heat lamps, heated mats, and enclosed brooders (Pedersen et al. 2016). Despite these precautions, piglets often remain close to the sow's udder for the first 24 hours, exacerbating hypothermia risk (Baxter and Edwards 2018). Localised heating maintains a suitable microclimate but has significant economic implications due to energy demands (Zheng et al. 2021). Even though these methods can effectively meet the thermal requirements of both sows and piglets, inconsistencies in the distribution of heat across macro- and micro-environments can result in delayed maturation and higher pre-weaning mortality (Morello et al. 2018). Also, warming and drying the piglet following birth has been successful in counteracting the rapid post-partum evaporative cooling and stabilising rectal temperatures post-partum (Van de Pol et al. 2020). High humidity itself may not affect pig productivity, but when combined with high temperatures, it causes heat stress and affects growth and reproduction negatively (Ross et al. 2017). Heat stress has been reported to prolong farrowing duration, increase stillbirths and piglet mortality (Oliviero et al. 2008), along with higher disease prevalence in sows, suppression in feed intake, and lower milk output (Iida et al. 2021), which further increases the risks of piglet mortalities (Nuntapaitoon et al. 2019).

6. Management practices

6.1 Farrowing assistance

Active supervision during farrowing has been widely acknowledged as a crucial factor in reducing neonatal piglet mortality (Edwards and Baxter 2015; Blavi et al. 2021; Tucker et al. 2021). Farrowing supervision by trained personnel that allows for timely intervention is the most reliable way of ensuring high piglet survival (Gopakumar and Deka 2020). However, the unpredictability of labor onset in sows still limits the success of farrowing supervision (Tucker et al. 2021). Approximately, about 24% of sows producing an average of 17.5 piglets per litter need at least one assisted intervention in farrowing to ensure the survival of piglets (Feyera et al. 2018). The establishment of highly prolific sows in modern breeding programs has increased the problems related to the emergence of dystocia, which manifests as prolonged farrowing durations and high stillbirth rates (Björkman et al. 2017). The proportion of sows requiring assistance in farrowing varies from 5.7% to 53.3% even among farrowing barns (Wongwaipisitku et al. 2023). However, this is highly associated with the parity of sows rather than with litter size. The most high-parity sows also required more assistance with farrowing, and nearly 20% of piglets born under such conditions are delivered manually, a practice that increases piglet survival. However, there is ongoing debate regarding the possible negative consequences of such interventions that interfere with the natural birthing process, may induce stress and contribute to postpartum complications in sows (Yun and Valros 2015), which could in turn affect sows' productivity and piglets' survival (Lagoda et al. 2022). Timely management actions such as drying and relocating newborn piglets to heated zones or positioning them at the udder significantly improve survival rates (Van de Pol et al. 2020). Furthermore, if piglets fail to initiate breathing within 15 seconds post-delivery, interventions such as clearing the amniotic sac, removing mucus from the nasal passages, and stimulating circulation through gentle rubbing can enhance viability (Revermann et al. 2018). As a herd management strategy of a preventive nature, reducing the proportion of high-parity sows (≥7) in herds has been recommended to lower the need for farrowing assistance (Wongwaipisitku et al. 2023).

6.2 Cross-fostering strategies

Cross-fostering (CF) is a common farming practice in commercial pig production, where one or more piglets from a large litter size are transferred from their biological dam to a nursing sow (Nielsen et al. 2022). This approach is primarily used to enhance the growth and survival of piglets during lactation and to standardise litter weight distribution (Alexopoulos et al. 2018). Effective CF is facilitated by selecting sows with good maternal characteristics and high milk production capacity, as these traits positively influence piglet growth performance and survival (Illmann et al. 2016). Nevertheless, Baxter et al. (2013) cautioned that CF should be kept to a minimum, as it can introduce stress to both piglets and sows. Piglets typically develop a preference for a specific teat within the first few days postpartum, therefore, CF should ideally be performed within 12 to 24 hours postpartum, before the teat order is initiated (Nielsen et al. 2022). Late fostering results in increased competition among piglets and a lower chance of securing a favourable teat position, which can impair growth and reduce survival rates (Zhang et al. 2021). Early CF also maximises colostrum intake from the piglet's biological dam, which is essential for immune development and lowering pre-weaning mortality.

7. Management strategies to improve piglet survival

7.1 Monitoring and record keeping

Precise observation and standardized records are key to improving piglet survival. Production information assists in the identification of high-performing sows, selection for reproductive traits, and in the early detection of health challenges (Garcia and McGlone 2018). Parameters related to the farrowing are farrowing outcomes, piglet deaths, sow feed intake, and adherence to treatment protocols, all of which affect pre-weaning survival (Tucker et al. 2021). Advances in Precision Livestock Farming (PLF) have made it feasible to continuously monitor livestock health, behavior, and environmental conditions by use of sensors, to facilitate timely information-based intervention (Morrone et al. 2022; Castellanos 2025).

7.2 Implement health management programs

Successful health management to reduce neonatal mortality includes colostrum feeding, biosecure cross-fostering, and provision of a clean and thermoneutral environment to avoid hypothermia (Blavi et al. 2021). Routine management practices need to be well-timed to minimize stress, while primary preventive measures such as strict biosecurity, control of incoming stock and sanitation of farrowing facilities reduce exposure to pathogens (Attupuram et al. 2025). Early diagnosis and management of sick piglets is essential to reduce pre-weaning mortality (Tucker et al. 2021).

7.3 Optimising farrowing management

Supervised farrowing enhances piglet survival through the provision of instant care to assess compromised neonates and by lowering the number of stillborn piglets (Edwards and Baxter 2015; Blavi et al. 2021). Inducing and synchronizing farrowing enhances labor efficiency, but such practices need to be performed at the right time to impede the occurrence of farrowings that are too early (Monteiro et al. 2022). Analgesic medication, including Non-steroidal anti-inflammatory drugs (NSAIDs), contributes to improved sow welfare and maternal behavior, and indirectly piglet survival (Bates 2015).

7.4 Optimising sow management

Maternal health, body condition, and nutrition during gestation are crucial for embryonic survival and subsequent piglet viability. Feeding management is also important when gestating sows are group-housed, to minimize aggressiveness and to achieve even nutrient distribution (Jang and Oh 2022). Good nutrition in early gestation promotes foetal growth and decreases the risk of stillbirth (Marshall et al. 2022). Enrichment materials such as, optimal slatted floor, and favorable environmental housing conditions contribute to improved sow welfare and maternal behavior and consequently to piglet survival (Zeng and Zhang 2023).

7.5 Optimising environmental conditions

Housing design strongly influences piglet survival. Sow mobility and sow-piglet interactions are enhanced in systems such as PigSAFE pens compared to farrowing crates, which in turn enhance piglet survival and welfare (Baxter et al. 2021; Singh et al. 2017). Enrichment items that lessen stress and enable the expression of natural behaviors, such as appropriate stocking density and use of straw bedding, decrease aggression and injuries (Torrison and Cameron 2019; Chidgey 2024). In hot climates, reflective roofing, ventilation, localized heat, and cooling systems alleviate heat stress in sows and young piglets, improving their potential for survival under harsh conditions (Ziaeemehr et al. 2023).

8. Prospects and opportunities

First, pre-weaning survival is a major factor to facilitate the rational selection of sows and piglets, and be beneficial for improving production performance, welfare, and economic benefits of the pig industry. Genomic selection has provided additional benefits in the discovery of genes associated with piglet vitality and survival. Also, further studies on the improvement of sow productivity without compromising litter quality may lower culling rates and result in favorable economic and welfare impacts for producers. Precision technologies, which include benchmarking systems and early-warning models, offer potential to enhance swine disease control. But the potential of these technologies is largely unmet due to data collection and contextualization issues. The absence of relevant information recorded from piglet death further complicates the construction of accurate intervention models. Meeting this challenge will require the integration of large and high-quality datasets generated in the areas of behavioral, environmental, and medical science, bridging the gap between technology advances and tools that can be implemented across the pig industry.

9. Conclusions

The drive for larger litter sizes and higher weaning rates per sow over the years has led to challenges, including lower birth weights, lower survival, and higher pre-weaning losses. Although there are continual endeavors to improve survival in the pre-weaning period, piglet survival is an intractable and multifactorial problem that has great implications for animal welfare and farm profitability. As piglet survival is a complex trait, this review emphasised the need for an integrated approach to be applied to the improvement of piglet survival that considers all causes in a pig production system. Utilization of an integrated approach, including genetic selection, optimized environmental conditions, targeted nutrition, and appropriate management conditions, is necessary to produce robust piglets that can survive throughout their growing and finishing phases. Ultimately, long-term sustainable gains in piglet survival must be achieved through balancing the sow and piglet phenotypes in favor of both production efficiency and high animal welfare.

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