https://doi.org/10.17221/36/2024-CJAS

The impact of parity, litter size and birth weight variations within a litter on piglet pre-weaning performance

Nqobile Lungile Buthelezi[1,2]*, *Bohani Mtileni*[1], *Khathutshelo Agree Nephawe*[1], *Peter Ayodeji Idowu*[1], *Mamokoma Catherine Modiba*[1], *Hezekiel Mpedi*[2], *Takalani Judas Mpofu*[1]

[1]*Faculty of Science, Tshwane University of Technology, Department of Animal Sciences, Pretoria, South Africa*

[2]*Topigs Norsvin-Animal Genetic Centre, Farm Bossemanskraal 538 JR, Bronkhorstspruit, South Africa*

**Corresponding author: nqoshenge11@gmail.com*

Citation: Buthelezi N.L., Mtileni B., Nephawe K.A., Idowu P.A., Modiba M.C., Mpedi H., Mpofu T.J. (2024): The impact of parity, litter size and birth weight variations within a litter on piglets' pre-weaning performance. Czech J. Anim. Sci., 69: 255–268.

Abstract: Sows are selected for their prolificacy. Therefore, assessing difficulties that can be associated with large litters is crucial. This review aims to highlight the factors that can affect reproductive performance such as breed, parity, litter size, environment, and nutrition. Understanding these factors can help producers make informed decisions about sow management and other aspects. Higher within-litter variation is the result of a high number of piglets born. It has been determined that large litter sizes pose a risk to animal welfare in the pig industry. Moreover, large litters bring more piglets with low birth weight leading to high pre-weaning losses. Lighter littermates struggle to get enough colostrum due to the competition with heavy littermates, which lowers their chances of survival causing high mortality. Larger litters may cause greater stress and discomfort of the sow. Therefore, applying stress-free environment and treating the sow with anti-inflammatory compounds may enhance the sow performance and consequent survival of piglets. The litter size is positively correlated with the variation in birth weight within a litter, while the average weight at birth is negatively related to litter size. Producers should therefore focus on potential management strategies that can improve piglet performance, survival and welfare such as proper supervision and adequate colostrum intake. This review highlights the historical development of the pig industry and literature on the variation in piglet weight at birth within a litter, factors influencing weight at birth, and the potential effects on the piglet performance before weaning. Also, the difficulties amongst large litters and possible strategies for managing survival in large litters were also reviewed.

Keywords: colostrum; cross-fostering; littermate; mortality; swine production

The South African pig production sector is regarded as an essential aspect of the country's farming economy (VandeWaal and Deen 2018). This industry consists of both commercial and small-scale pig producers, and it primarily focuses on pork production for local consumption (VandeWaal and

Supported by the Topigs Norsvin SA (No.?) and by the Tshwane University of Technology Postgraduate Scholarship (No?).

https://doi.org/10.17221/36/2024-CJAS

Deen 2018). There are approximately 2 000 commercial pig producers in South Africa across the country. These producers account for most of the country's pork production, with smaller-scale farmers making up the remainder. The South African pig industry is facing some challenges, such as high feed costs, disease epidemics, and opposition to introduced pork products. However, the industry has also made significant strides in recent years, with efforts to improve breeding, genetics, and production techniques (Ahmar et al. 2020). In addition to pork production, pig production is also involved in the production of other pig-derived products, such as bacon, ham, and sausages (Matabane et al. 2018). These products are sold both domestically and internationally, with exports primarily going to other countries in Africa. Overall, the South African pig industry plays a significant part in meeting the protein needs of the population. One of the factors that are responsible for the success and challenges of pig production in South Africa is the pre-weaning performance of piglets.

Piglet pre-weaning performance is an essential factor in the pig industry, as it affects the profitability of pig farming (Grobler et al. 2016). To optimise the maturation and improvement of piglets, it is essential to understand the factors that influence their pre-weaning performance. Previous findings have proven that parity, litter size, birth weight (BW) and variation of piglet weight at birth within a litter significantly influence the piglet performance before weaning (Riddersholm et al. 2021). For instance, sow parity may affect the composition and quantity of milk produced, which may influence the development and survival of her piglets. Similarly to higher litter numbers, smaller litter sizes could not stimulate the sow's milk production adequately, resulting in increased resource competition and slower growth rates. Another crucial element is weight at birth, as piglets with lower BWs are more prone to have health issues and grow at a slower rate (Howe et al. 2020). Pre-weaning performance can also be impacted by variations in BW within a litter since these variations may reflect varying food intake during pregnancy, which could be responsible for variations in growth rates within the litter (Lopez-Soria et al. 2019). Understanding the effects of these factors on pre-weaning performance can help producers make informed decisions about sow management, litter size, and other aspects of pig farming. This can ultimately lead to better outcomes for piglets, improved productivity, and increased profitability for farmers (Blavi et al. 2021).

Therefore, this paper critically reviews the historical improvement in the pig industry, the literature on the variation in BW within a litter, factors influencing it, and the potential effects on piglet performance prior to weaning. Also, the difficulties amongst large litters and possible strategies for managing survival in large litters were also reviewed.

MATERIAL AND METHODS

An electronic search in Google Scholar, PubMed, Science Direct and SciELO databases was used to gather information for the review. The keywords that were used include colostrum, littermate, mortality, cross-fostering, and swine production. The words were used to search for as many articles as possible. A total of 109 articles were selected. During the research, only articles discussing the pre-weaning performance of piglets according to parity, litter size and BW variations were selected.

Birth weight: A major factor for weaning weight

Piglet weight at birth is the most significant factor of weaning weight, the main component of weaning capability. Even though it is challenging to manipulate, there are several strategies to improve it (Yuan et al. 2015). The most common way to improve piglet viability is by increasing the sow nutrition settings in the last 21 to 28 days of maternity, which is usually 2.6 kg in primiparous sows and 2.8 kg in multiparous sows. Although the effect on weight at birth is usually minor, this method was found to have a positive effect on piglet viability. Recent research indicates that adding oil to the diet (about 5% of oil) may result in fewer stillborn piglets, better endurance for smaller piglets, and improved weaning weights (Swiątkiewicz et al. 2020; Vodolazska and Lauridsen 2020). To enhance BW, accurate feed levels and attention to sow health during the breeding cycle are essential (Vodolazska and Lauridsen 2020).

In practice, weight at birth is the common sign of piglet's ability to live up to weaning (Feldpausch et al. 2016; Tucker et al. 2021). Several authors

https://doi.org/10.17221/36/2024-CJAS

(Magnabosco et al. 2016; Zotti et al. 2017; Romero et al. 2022) have looked at the long-term effect of light weight at birth on piglet endurance and maturation, but their results on the piglet capacity to make up for lost time and catch up with their littermates in terms of growth have been inconsistent. Although some have claimed that low BW piglets are more likely to exhibit poor pre-weaning maturation and lighter body weight at weaning, it has been shown that piglets with light weight at birth can counterbalance in post-natal development (Howe et al. 2020). In addition, piglets with lower BW have slower lifespan growth rates and more life before market weight than piglets with higher BW (Howe et al. 2020).

According to Nuntapaitoon et al. (2018), other than birth weight as the indicator of pre-weaning growth and survival, intra-uterine growth restriction (IUGR) can also affect the performance of piglets. While some small foetuses are naturally small but healthy, some are the outcome of placental inability, which can lead to IUGR piglets. These neonates contribute significantly to pre-natal death in numerous species. Delayed foetal growth can be categorized into two types: unbalanced and balanced. Unbalanced growth refers to a body that is extremely smaller than the head, while balanced growth affects the head in part to the rest of the body. As per Amdi et al. (2017) and Huting et al. (2018), the most common type of IUGR piglet is asymmetrical, which is characterized by a dolphin-like head shape.

The IUGR pigs develop in a dilatory way compared to their littermates, with a reduced vigour reserve, immature organs, and anosmic gastrointestinal system development (Hales et al. 2014).

Factors influencing the birth weight and within-litter variation

Several factors affect weight at birth and within-litter variation in pig production, including breeds, parity, temperature, litter size, and management, among others. These variables all play a role in within-litter weight differences. Therefore, it is crucial to concentrate on pre-service and gestation periods to enhance oocyte and conceptus development uniformity, minimize variation during implantation, and improve newborn piglet weight (Yuan et al. 2015).

Breed/strain. The pig breed is a crucial factor in determining their reproductive performance, with both purebred and crossbred sows being used by producers in their efforts to increase productivity (Knecht et al. 2015). According to Getahun et al. (2019), crossbreeding is particularly beneficial due to the hybrid vigour it imparts, resulting in positive effects on traits like fertility and survivability, which have low heritability. This, in turn, translates to improved conception rates, birth weights, litter sizes, and weaning rates. Moreover, crossbred dams also exhibit maternal heterosis, which enhances piglet weight, including birth weight, within-litter variation, and weaning weight, as well as litter size (Pedersen et al. 2019).

According to research, breed is a significant factor that affects reproductive performance in pigs. To address this issue, crossbreeding has been identified as an effective method to improve generative production because of the low heritability of reproductive traits (Hagan and Etim 2019). Furthermore, a larger number of piglets born is an indication of the inherent perspective of the breed's generative biology, as well as the cros bred's ability to withstand environmental factors like weather conditions, nutritional factors, and other similar challenges (Hagan and Etim 2019). The most popular breeds used in crossbreeding are Large White (LW) and Landrace (L) breeds due to their great performance in the pig industry. LW are normally selected as dam lines in breeding programs because of their outstanding number of piglets born and healthier litter with high survivability (Rothschild and Ruvinsky 2011), while L pigs are commonly used as a sire line because of their high fertility (Pedersen et al. 2019). The LW and L produce a high number of born alive piglets and increased litter weight at birth (Amatucci et al. 2022). Nevertheless, the larger number of piglets born is associated with light weight piglets at birth and the increase in within-litter variation, consequently, increases pre-weaning mortality. The use of crossbreds improves conception rates leading to a higher pregnancy rate, farrowing and higher litter size (Hagan and Etim 2019) although this can result in high pre-weaning mortality. Piglet survival rates are due to the mothering ability of the sow (Edwards and Baxter 2015), thus high litter size at birth may lead to negative effects when the dam receives insufficient diet to make adequate milk in the early period after parturition.

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Parity. The impact of parity on piglet weight at birth is the cause of the large number of piglets born, which results in greater variability (Zindove et al. 2013). Litter size tends to increase up to parity 3 and then it declines with the dam's age. The increase in age leads to the increase of stillborn piglets, and birth weight becomes more variable. Older sows with higher parity tend to have fewer uniform litters and a higher proportion of light weight piglets at birth (Yuan et al. 2015; Charneca et al. 2023). In contrast, piglets born to primiparous sows tend to have much uniform birth weights (Yuan et al. 2015). Litter size has a positive relationship with parity, with the highest levels typically reached between parity 3 and 5 (Freyer 2018). However, the negative impact of parity on litter uniformity is possibly due to its association with birth weight variation within a litter, which tends to rise with larger litter sizes (Quesnel et al. 2014). Moreover, the birth weight variation tends to be higher in older parities after accounting for the total number of pigs born (Wientjes et al. 2013). Some researchers have suggested that the change in litter similarity in old sows may be due to the decline in oocyte quality that accompanies aging (Yuan et al. 2015), indicating that parity can have an important impact on litter uniformity in terms of BW.

Temperature. Pigs have a predisposition to heat stress as they do not sweat very much and rely on evaporative cooling according to Boddicker et al. (2014). Unfortunately, modern genetic selection has exacerbated this issue, since pigs are selectively bred for excessive lean tissue growth, increasing their basal heat production, as noted by Johnson et al. (2015). When pregnant sows face heat stress, it can lead to changes in the growth, body composition, and metabolic function of piglets, with the severity of these changes dependent on the duration and intensity of stress, as outlined by Boddicker et al. (2014) and Johnson et al. (2015). These changes are brought about by alterations in metabolism and uterine blood flow, leading to differences in skeletal and intestinal growth, as well as hormonal and metabolic profiles. This can have a negative influence on piglet growth and performance, as highlighted by Dhakal et al. (2013) and Boddicker et al. (2014). Additionally, Rutherford et al. (2013) suggested that utero-placental vascularity differences may affect some piglets more than others, leading to variations in weight and growth.

Litter size. The breeding of highly productive sows causes an increase in the number of pigs born (Koketsu et al. 2017). However, a large number of piglets born causes a decrease in weight at birth and an increased variation within a litter (Charneca et al. 2021; Peltoniemi et al. 2021; Nam and Sukon 2022). Low BW piglets are disposed to perinatal death (Nam and Sukon 2020) and have a lower endurance rate and lower growth rate (Riddersholm et al. 2021; Nam and Sukon 2022). Increased litter size leads to a huge proportion of light piglets having insufficient body strength, resulting in sensitivity to cold (Kitkha et al. 2017). Besides, they struggle to compete with their littermates for adequate colostrum and milk consumption, leading to higher chances of death in the early days after birth (Kitkha et al. 2017).

Maintaining an optimal litter size is crucial in the pig industry, and as such, reducing litter size is not encouraged due to its impact on profits (Zindove et al. 2013; Marandu et al. 2015). A larger litter requires a plenty of nutrients before and after parturition, which can be challenging to provide (Baxter et al. 2013). However, improved litter size can lead to increased milk production, which then requires more energy from the sow to sustain production due to suckling intensity (Muns et al. 2023). If the sow experiences a body condition loss, this can result in compromised foetal development, leading to higher variation within a litter (Rutherford et al. 2013; Wientjies et al. 2013). Furthermore, the sow's ability to balance increased feed consumption is reduced, and low consumption can affect generative hormone levels, specifically those with an impact on follicle development (Langendijk 2021). This can significantly impact on post-lactation production by delaying follicular development and oestrus (Bierhals et al. 2012; Soede et al. 2015). To alleviate the stress of large litters, re-homing piglets is practised instead of selecting against it (Pedersen et al. 2019).

Challenges associated with larger litter. In the pig farming industry, sows are carefully chosen and bred for their ability to produce larger litters, ultimately resulting in a higher number of pigs being sold each year (Yuan et al. 2015). However, as producers strive to increase litter size, it is essential to consider potential issues that may arise and determine if these challenges could be successfully controlled or need medical interference (Ward et al. 2020). As litter size increases, sows

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face various obstacles, including higher rates of pre-weaning and post-weaning mortality, and developmental concerns (Tucker et al. 2021).

Intrauterine crowding and its effect on piglet improvement. Even though the sows can give birth to larger litters, it is crucial to keep in mind that the uterine space and body fluid provision are restricted assets, as supported by research conducted by Pardo et al. (2013), Madsen and Bee (2015), and Langendijk et al. (2016). Typically, a sow will begin pregnancy with approximately 15–20 viable embryos, with only 9–13 eventually developing into live piglets, as Greenwood et al. (2014) have shown. Despite this, it is worth noting that commercial production has seen litters greater than 16 piglets become increasingly common, as observed by Fijn et al. (2016) and Roelofs et al. (2019). In cases where the litter size is larger, the sow uterus can become crowded with embryos, leading to embryonic competition. This competition can occur as the first implanted embryos limit the process of joining embryos, and the contest rises with each thriving immature attachment, as indicated by Ward et al. (2020).

Moreover, when the uterus surpasses its normal capacity, each additional littermate results in a decline in individual foetal growth (Ward et al. 2020). As a result, a larger litter size is strongly connected with a substantial balance of piglets being born with low weight (less than 1.0 kg), as noted by Madsen and Bee (2015) and Schmitt et al. (2019). These piglets with light weight at birth have a higher surface area to volume ratio, they are vulnerable to poor viability, weakened immunity, hypothermia, and hypoglycaemia in the early hours of birth (Ward et al. 2020). Thus, light-weight piglets have a higher hazard of mortality before weaning compared to their average-weight counterparts (Zeng et al. 2019).

Additionally, intrauterine crowding can impede the physiological development of the foetus during gestation (Amdi et al. 2013). The piglets affected by IUGR not only exhibit a disproportionate physical appearance at birth, including the head shape reminiscent of a dolphin, as noted by Amdi et al. (2013), Hales et al. (2014), and Chand et al. (2022), but they also suffer from immature intestinal development, leading to metabolic compromise (Engelsmann et al. 2019). Inflammatory and metabolic profiles are further disturbed in these piglets, as highlighted by Huang et al. (2019) and Wen et al. (2022). Piglets exposed to intrauterine restriction exhibit insufficient milk consumption and hepatic glycogen, resulting in higher morbidity and mortality rates, as well as hypothermia (Magnabosco et al. 2015; Vallet et al. 2016).

Higher incidence of piglets being crushed by a sow. Researchers have reached a consensus that the primary reason for early piglet death is the overlaying by the sow. Contributing factors include pig breed and litter size, increased sow parity, bad mothering ability, and reduced birth weight. Additionally, sows or gilts experiencing stress and irritation during the periparturient period are restless and maximize the possibility of crushing, especially if the sow immediately lies down. According to Ward et al. (2020), crushing can potentially be a scheme to minimize maternal investment in larger litters, since the prevalence of sows crushing any piglets was greater for prolific sows. Weak piglets and those with lower viability are more susceptible to being crushed (Muns et al. 2017).

The welfare of piglets plays a crucial role in their survival until they are weaned. Research shows that pre-weaning survival is positively associated with birth weight uniformity within a litter from a genetic perspective (Charneca et al. 2023). Piglet survival is linearly correlated with the coefficient of variation for birth weight within a litter, while the relation between mean birth weight and mortality is curvilinear (Pardo et al. 2013; Yuan et al. 2015). Uniformity in litter birth weight is also linked to higher survival rates and improved welfare (Zindove et al. 2013; Charneca et al. 2021). According to Marandu et al. (2015), individual weight at birth has a more significant impact on piglet survival compared to relative birth weight. Additionally, male piglets have a greater mortality rate caused by higher basal cortisol levels, making them more susceptible to stress. Higher within-litter variability increases the likelihood of mortality before weaning, as smaller piglets must contend with heavier ones for resources. This contest leads to lighter piglets remaining closer to the dam for a longer time, increasing their risk of getting crushed (Yuan et al. 2015). It has been determined that litters with a reasonable size of 10 to 14 piglets are more likely to survive up to weaning (Marandu et al. 2015).

Potential strategies for managing survival in large litter

The quantity and quality of piglets that are weaned and their subsequent performance in a later phase

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of production are affected by the level of attention and management given in the farrowing housing. The best management strategies to reduce piglet mortality are to increase birth weight and improve heating (Harper and Bunter 2024), giving the piglet more energy to stay far from the sow (Ward et al. 2020). Birth weight can be built through exclusive breeding, nutrition (Renteria Flores et al. 2021), and early fostering (Zhang et al. 2021). All these management strategies include managing integrated piglets and sow management, colostrum intake, environment, nutrition, and herd parity structure management.

Integrated piglets and sow management. Piglets that lack uniformity in size require more intensive management, which can lead to increased costs including feeding (Yuan et al. 2015; Tian et al. 2016). For instance, smaller piglets may need more time to get the market weight compared to larger littermates, which can impact on the overall cost of production. To address this, piglet transfer is a popular practice in pig production to balance litter numbers and minimize the influence of BW variation (Heim et al. 2012). However, this process needs extra effort and time. To ensure the survival and proper colostrum sharing of small piglets, cross-fostering should take place as soon as possible following the birth, preferably within 24 h or sooner after farrowing. In cases where this is not feasible, split suckling can facilitate colostrum sharing in larger litters (Romero et al. 2023). Mortality rates can increase if piglet numbers are higher than the sow rearing ability, making fostering a necessary practice across the industry. This helps to re-home piglets associated with increased sow prolificacy in relation to the number of available useful teats (Vande Pol et al. 2021; Oliviero 2023). Additionally, fostering can guarantee litter uniformity by reducing variability in weaning weight, which can have subsequent impacts on slaughter management (Van den Bosch et al. 2019). However, the process of relocating a piglet from one birth mother to another can be challenging. It can result in changes to the surroundings, littermates, and sow, which can be disadvantageous for the moved piglet and may irritate the litter to which it is transferred (Baxter et al. 2013; Schmitt et al. 2019).

In the typical all-in-all-out system, variation poses a challenge, as pigs must be sorted by weight rather than by age. However, this system has the benefit of preventing disease transmission by halting the infection and inhibiting the accumulation of pathogens through facility disinfection between groups. Additionally, it enhances feed productivity and everyday strength, ultimately resulting in fewer days to merchandising and decreased feed prices (Aymerich et al. 2020). The increased uniformity achieved through this system also allows for easier management and lower mortality rates, and consistent size and weight of the final product, and also quality attributes such as colour, marbling, and drip loss, prove advantageous for both retailers and consumers alike (Roche et al. 2010). It is worth noting that variation in pig weight and shape can result in controlling troubles and product regularity matters which would be detrimental (Zindove et al. 2013; Mulder and Rashidi 2015). Given that profitability is tied to slaughter and management procedures, it is prudent to opt for sows that give more homogeneous litters (Zindove et al. 2013).

Colostrum consumption. Newborn piglets have lower energy levels and fewer protective antibodies, making them reliant on colostrum from the sow immediately after birth to provide them with energy and protection against harmful pathogens like viruses and bacteria (Rasmussen et al. 2016). Foremilk, which is the first milk produced by the sow, is an essential source of nutrients, resistance, and energy for the piglet (Silva et al. 2019). Immediately after giving birth, it is secreted from the udder and its composition changes within a few hours to match that of sow milk (Silva et al. 2019).

During birth, piglets experience a sudden shift in their energy supply as they begin to feed. In addition, the environment in which they are born is usually quite cold. Due to their high surface area to volume ratio and wet skin, new-born piglets lose heat quickly, causing a sharp drop in their body temperature (Theil et al. 2014). With < 2% body fat and high vigour demands, piglets get into a negative energy balance soon after birth (Theil et al. 2014). Therefore, it is crucial for piglets to consume colostrum shortly after birth to maintain their energy balance. Colostrum is most beneficial when obtained from a piglet's birth sow. Recently, it has been revealed that colostrum contains certain aspects of immunity (cell-mediated immunity) that are only present in piglets that have been preserved on their original dam for more than 12 hours (Bandrick et al. 2014).

Research has proved that light birth weight piglets (800–1 200 g) have an over 89% chance of surviving

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until weaning if they receive about 200 ml of colostrum (Moreira et al. 2017). Declerck et al. (2016) also reported a similar observation, finding that a correlation exists between inadequate colostrum ingestion and decreased survival before weaning, with the higher effects in piglets with lower weight at birth. Furthermore, colostrum has a significant impact on the development of the neonatal gut (Ward et al. 2020). Colostrum provides essential nutrients for vigour, growth, and development to neonates for their transition from the placental supply of substantial nutrients such as glucose and amino acids after birth (Sangild et al. 2021). Additionally, colostrum offers immune protection that assists the element of neonatal innate immunity up to the maturation of adaptive immunity to the environment (Sangild et al. 2021).

In managing larger litters, it is important to prioritize the colostrum ingestion of lower weight pigs. A viable approach is the split suckling technique, as demonstrated by Alexopoulos et al. (2018) and Tang et al. (2023). This technique includes dividing the piglets into different groups, with the heavier piglets temporarily separated to allow smaller piglets' access to the udder and benefit from colostrum intake, a strategy supported by Kirkden et al. (2013) and Vandaele et al. (2020). The ultimate purpose of split suckling is to minimize competition for colostrum (Morton et al. 2019).

Environmental management. The viability and survival of embryos may be largely dependent on the quality of the oocyte, which is in turn affected by various factors including maternal situation, nourishment, temperature, and sow age (Swinbourne et al. 2014). The number of pigs per litter is given by the number of fertilized and released gametes that evolve into viable offspring. According to Swinbourne et al. (2014), the smaller oocyte size during temperate times can lead to smaller litters due to the heat impact on hormone production and oocyte competence. Heat stress during gestation can be particularly detrimental in the first half of the time (Boddicker et al. 2014). Fibre growth in pigs is limited to days 35 and 90 of maternity, and heat stress during early gestation can negatively impact on the primary fibre growth, leading to suboptimal performance (Boddicker et al. 2014). Johnson et al. (2015) also observed that heat-stressed piglets had smaller organs, especially the liver, which plays a part in energy production for the first few days of life because of its high glycogen concentration (Theil et al. 2014). These factors can lead to variable BWs within litters as they affect individual piglets differently *in utero*.

During two hours after farrowing, immature piglets are particularly vulnerable to the physiological state. The type of flooring in their environment can have an impact on their body temperature, as metal slats can lower their rectal temperature when compared to solid concrete floors (Pedersen et al. 2016). To optimize piglet performance, the plastic-coated expanded metal flooring is a better option than concrete slats (Ramirez et al. 2022). The most effective way to manage piglet environments is to maintain two distinct microclimates – one for piglets kept at a temperature of 30–35 °C, and the other for sows kept between 18 and 20 °C. This approach reduces utility costs and minimizes the sow heat stress compared to the entire farrowing house, while still supporting piglet needs (Ramirez et al. 2022). To create an ideal microclimate for piglets, it is important to consider the type of supplemental heat source and adequate space allocation (Ramirez et al. 2022).

Nutrition. During pregnancy, the developing litter is granted high precedence for vigour and nutrients, though the demand is quite small. As a result, it is improbable that ingestion levels during maternity will have an impact on litter size under normal commercial conditions (Harper and Bunter 2024). Additionally, it has been found that excessively high vitamin levels in herds with normal diets do not increase the litter size. However, experiments conducted in Canada have revealed that severely limited feed consumption in any week of suckling can affect ovulation rate, embryo survival, and ultimately litter size (Theil et al. 2014; Renteria et al. 2021).

According to Liu et al. (2020), feed consumption of sows during gestation can also affect piglet birth weight similarity. The intake of cycling gilts at or below the maintenance level, as opposed to *ad libitum*, has been shown to decrease oocyte maturation (Swinbourne et al. 2014). This difference in gametocyte growth rates inside the uterus, potentially due to uneven nutrient accessibility to the foetuses, can result in variations in foetus and piglet weight. The litter-of-origin consequence may also impact on the future generative productivity of gilts, as larger litters can decrease colostrum availability and hinder neonatal uterine gland development (Vallet et al. 2016).

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To increase ovulation rate and litter size, it is recommended to feed gilts quality diet *ad libitum* at least 10 d prior to breeding. However, feeding gilts a higher ration (more than 2.5 kg feed/day) in 48 h to 72 h after breeding can minimize the embryo survival (Theil et al. 2014; Renteria et al. 2021) and ultimately the litter size.

Herd parity structure management. In order to consistently produce the highest quality piglets, it is essential for the herd parity structure to remain stable. This can only be achieved through a consistent influx of gilts into the herd, maintaining a greater number of females in the 3–6 parity range, and strictly culling based on age after 7–8 parities. Failing to maintain a balanced parity structure due to the uneven gilt section, high removal rates among immature females or poor culling policies can create unwanted variations in mean litter size and birth weight over time. This, in turn, can have several counter implications for the maturation and efficiency of pigs from weaning to market (Marandu et al. 2015). Both piglet survival and litter weaning weight decrease after the sow approaches the third or fourth parity (Zeng et al. 2019). The likely explanation for reduced piglet survival is enhanced sow unwellness stress acting to ease milk yield (Tummaruk and Sang-Gassanee 2013) and poor teat availability (Tummaruk and Sang-Gassanee 2013). Furthermore, older sows are more disposed to lameness (Li and Gonyou 2013) and this can lead to a high risk of crushing (Pluym et al. 2013), causing a high mortality rate.

The productivity of breeding herds is mostly assessed by the number of pigs weaned per sow per year (Koketsu et al. 2017). However, pigs weaned per sow per year are a good indicator of the herd ratio, but not of sow longevity and piglet quantity (Koketsu et al. 2017). As the number of pigs born alive increases, the birth weight decreases, and small piglets fail to consume sufficient colostrum from the sow. Therefore, lighter birth weight and insufficient colostrum consumption result in higher pre-weaning mortality (Declerck et al. 2016). The number of pigs born per sow per year is influenced by the farrowing rate and culling intervals because of unproductive days caused by abortion in commercial herds (Iida and Koketsu 2015; Declerck et al. 2016).

The fertility and prolificacy of sows depend on the herd sow management including gilt development program, time of insemination, farrowing and lactation management and culling strategies (Koketsu et al. 2017). Kaneko et al. (2013) indicated that gilts inseminated immediately after oestrus detection have higher farrowing rates than those with delayed insemination. According to Koketsu and Iida's (2020) findings, the recommended culling interval for mated gilts and sows was exceeded by a minimum of 30 days. As a result, producers should employ echography reproduction of ovaries in gilts to determine the timing of insemination in connection with ovulation, as suggested by Koketsu et al. (2017).

Birth weight within-litter variation management. Managing the low uniformity piglets can be challenging. For example, smaller piglets may require an additional time to get to the market weight when compared to their larger littermates, leading to an increase in feeding costs (Yuan et al. 2015; Tian et al. 2016). To address this issue, piglet relocation is a popular practice in pig farming, which involves merging the litter size to the number of teats and mitigating the impacts of birth weight variation (Vande Pol et al. 2021). However, this process requires extra labour and time. In the model all-in-all-out system, sorting pigs by weight, not by age, is crucial due to variation. This system helps prevent disease transmission as facilities are disinfected between groups.

Consequences of birth weight within-litter variation

The consequences of variations in BW within a litter can result in lower pre-weaning growth performance, as well as impact on the vitality and survival of piglets, as noted by Yuan et al. (2015) in their study. This dispute about growth performance can be attributed to both the disparity in milk intake and the efficiency of nutrient utilization among littermates. Studies have confirmed that piglets with low weight at birth have a better chance of thriving during the pre-weaning stage if raised alongside piglets of the same weight, instead of the heavier ones (Huting et al. 2018; Vande Pol et al. 2021).

Pre-weaning growth performance. Studies have shown that there is a relation between birth weight variations in piglets and their pre-weaning growth performance within litters. These variations can be largely attributed to differences in colostrum consumption and nutrient utilization efficiency

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among littermates (Yuan et al. 2015). The consumption of colostrum, which is important for piglet growth and development, is influenced by piglet vitality at birth and competition among littermates for access to teats. The teat order constituted within the first 24 h after birth tends to persist. Studies have also found that heavier pigs have a high likelihood of endurance compared to their lighter littermates because they can consume larger amounts of colostrum. This is so because the ability to suckle more colostrum is linked to birth weight (Declerck et al. 2016; Tucker et al. 2021). Furthermore, higher BW and colostrum intake are also associated with better growth performance, as evidenced by studies conducted by Declerck et al. (2016), Le Dividivh et al. (2017), and Vodolazska et al. (2023).

Vitality and survival of piglets. Piglet vitality refers to the piglet capacity to survive from birth to weaning, as determined by its survival rate during this period (Tucker et al. 2021). Vigour and endurance traits are affected by additional genetic parameters (such as behaviour, vigour, immunity), maternal genetic parameters (such as behaviour, milk choice, and amount), uterus choice, average litter (such as litter size), and several situation effects (such as temperature, stress, and difficulties during farrowing, as well as assistance with colostrum intake), which are difficult to statistically identify (Heub et al. 2019). Birth weight is the primary determinant of piglet survival, and an alternative trait to consider when breeding for improved piglet endurance due to its high heritability (Heub et al. 2019).

Once body reserves and thermoregulatory ability are ensured, the main factor that influences piglet endurance is the vigour of the piglet instantly after parturition. Neonatal vitality can be measured through behavioural findings, such as the period to get to the udder, and physiological parameters, including the muscle tone. Piglet vigour varies significantly among littermates, and this change is influenced by the degree of hypoxia at birth (Farmer and Edwards 2020). The last-born piglets typically experience hypoxia. Neonatal asphyxia results in critical acidosis and has severe negative impacts on the function of essential organs. Decreased total vigour, weak thermoregulation, poor inactive transfer of immunity, weak performance, and higher susceptibility to infections are crucial secondary problems related to neonatal asphyxia and acidosis (Bailey et al. 2020). Low birth weight piglets have an enhanced risk of death and decreased weight gain during suckling. For instance, piglets with < 1 kg weight at birth are most likely to die prior to weaning (Marandu et al. 2015).

PROSPECTS AND OPPORTUNITIES

The study of the impacts of parity, litter size, birth weight, and within-litter birth weight variation on pre-weaning performance in piglets has significant implications for the future of pig farming. By understanding how these factors impact on piglet growth, health, and survival, producers can implement strategies to improve pre-weaning performance and overall productivity (Schinckel et al. 2010).

One opportunity for future research is the development of breeding programs that select for traits that promote better pre-weaning performance. This could include selecting sows with higher milk production or piglets with better growth rates and disease resistance. With the growing importance of animal welfare in agriculture, there is also a potential for research on how to optimize pre-weaning performance while ensuring the health and well-being of sows and piglets (Serenius et al. 2019).

Another opportunity is the development of innovative management practices that can help mitigate the negative effects of factors such as large litter sizes or low birth weights. For example, the use of foster sows or cross-fostering techniques can help redistribute piglets to ensure that they will receive adequate nutrition and care. Advances in technology and precision farming could also help improve the monitoring and management of sow and piglet health and nutrition (Wellock et al. 2014). In addition, there is a potential for the pig industry to expand and diversify its product offerings beyond pork, such as producing pig-derived pharmaceuticals or other value-added products. This could provide new revenue streams and opportunities for pig farmers.

CONCLUSION

Based on the literature reviewed, piglets born with lower weight face a higher risk of death, especially when they have not received sufficient colostrum intake. Poor pre-weaning performance is often caused by low BW and large litter size,

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which must be managed promptly. While economic considerations drive present management practices, a more ethical approach is necessary. Instead of focusing solely on the number of pigs weaned, producers must also consider the number of piglets that died to reach that figure. The endurance of smaller piglets during weaning is particularly challenging due to the enhanced risk of low BW and weight variation within the litter. Colostrum is vital for their survival, and piglets should receive it within 24 h of birth from their birth sow. When the sow's colostrum production is insufficient, fostering to another farrowing sow may be necessary. Split suckling can provide smaller piglets with a chance to suckle, and efforts should be made to ensure the even colostrum ingestion among litters. Piglet transfer should occur within 12–24 h after birth, and alternative schemes, including the use of foster sows, should be engaged if piglet movement must be avoided.

Acknowledgement

We thank Topigs Norsvin South Africa and the Tshwane University of Technology for their contribution to the study.

Conflict of interest

The authors declare no conflict of interest.

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Received: March 14, 2024
Accepted: July 15, 2024