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The nurse sow system – A natural process of handling large litters: A review

Joab Malanda Osotsi[1,2], Gabriella Novotni-Danko[1], Peter Balogh[3]*

[1]Department of Animal Science, Institute of Animal Science Biotechnology and Natural Conservation, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, Debrecen, Hungary
[2]Doctoral School of Animal Science, University of Debrecen, Debrecen, Hungary
[3]Non-independent Department of Research Methodology and Statistics, Institute of Statistics and Methodology, Faculty of Economics and Business, University of Debrecen, Debrecen, Hungary
**Corresponding author: malanda@mailbox.unideb.hu*

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Abstract: Reproductive performance in pig production has gained genetic momentum resulting in large litters. Several strategies have been used to raise the number of piglets to address the challenge of a large litter size. This review provides a rationale for employing the nurse sow system as a biological way of handling large litters, exploring its step-by-step processes and its selected impacts. By exposing these steps, pig farmers will use the information to pinpoint their weak points in the chain and customize the procedures to meet their farm-specific goals for improved productivity. The nurse sow system helps to maximize pre-weaning survival by boosting the overall worth of low birth weight piglets. When piglets weaned per sow/year are used as a performance benchmark, nurse sows weaning double litters become economically advantageous. Extended time in lactation for nurse sows gives them an ample time for their uterus to involute before the next pregnancy. However, nurse sows lose their body reserves reflected in backfat thickness from high milk production. Prolonged confinement in lactation deteriorates the physical condition of nurse sows, resulting in leg ulcers and teat damage. Additionally, piglets are more distressed when taken away from their biological sow to a new sow.

Keywords: fostering; piglet; pig production; selection

INTRODUCTION

Concerns about lactating sow in farrowing systems have grown, as the quantity of piglets produced by the sow surpasses the number of sow's functioning teats. This kind of a sow is referred to as a "Hyperprolific Sow" (HPS) (Oliviero 2023). Pig herds frequently contain hyperprolific sows that farrow a higher number of piglets than the number of their teats, triggering the use of extra management techniques to raise them. Many hyperprolific sows produce large litters of 18 to 20 piglets (Bjorkman et al. 2017; Thorsen et al. 2017; Kemp et al. 2018) and are restrained by the fact that they have typically 14–16 functional teats (Duijvesteijn et al. 2014; Dall'Olio et al. 2018). Common manage-

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ment strategies to rear large litters have been well described, among them, using nurse sows. The use of nurse sows has received considerable attention in aspects of strategies (Baxter et al. 2013; Bruun et al. 2016; Sorensen et al. 2016), welfare issues (Baxter et al. 2013; Sorensen et al. 2016; Alvasen et al. 2017; Schmitt et al. 2019) and lifetime performance (Bruun et al. 2016; Pokorna et al. 2020), hence such aspects will not be considered in this review.

LARGE LITTERS AS THE TRIGGER FOR USING NURSE SOWS

Research has revealed that large litter sizes are becoming more prevalent in pig production (Yun et al. 2019; Ward et al. 2020; Oliviero 2023). Large litters are characterized as having more piglets than the sow can nurse with the functional teats, regardless of whether the litter is stillborn or born alive. Litter size has significantly increased in recent years. For example, Knol et al. (2002) indicated that in 2002, 12.2 total born piglets were reported in sow herds in The Netherlands as opposed to 15.3 total born piglets in 2022 (Knol et al. 2022). According to the review by Theil et al. (2023) from 2000 to 2023, the number of piglets born alive increased from 12.5 to 21.7. This increased litter size is a result of improved breeding at the farm level. Improved research from the nucleus herds has produced exceptional prolific sows at multiplier levels, enhancing the genetic capacity of the sows to give birth to many piglets as the main force behind genetic improvement (Prunier et al. 2010). Due to increased genetic variability among pigs, pig breeders have been able to significantly enhance the total number of piglets born within each litter, measured by both the total born (live born, still born, mummies) and live born (Schild et al. 2020). Furthermore, given such a significance in genetic variation, pig breeders may still be able to enhance reproductive qualities (Zak et al. 2017), compounding the issue as the sow uterine capacity has a limitation of the number of piglets it can hold (Freking et al. 2016; Freyer 2018). From a general viewpoint, the benefits of increasing litter size could be advantageous, resulting in an increase in the pig population. This leads to increased pork production aimed at feeding the increasing human population. However, the advantages of larger litter sizes are not without drawbacks that are equally noticeable at the herd level in terms of management, housing, nutrition, disease control, and welfare.

Litter size defined as total number of piglets born is an indicator of sow reproductive efficiency that is used to compare productivity of breeds. In intensive pig production, differences in litter size between breeds are attributed to the fact that paternal breeds are mostly bred for production traits while maternal breeds are bred for reproduction traits (Nowak et al. 2020). Litter size is also an important trait considered when calculating economic value and genetic selection (Kanis et al. 2005). Additionally, pigs weaned per sow per year are an economic measure of sow's efficiency determined by litter size (Lay et al. 2002). However, large litters result in lower average birth weight of piglets (Quiniou et al. 2002) and within-litter variation (Lund et al. 2002). The large litter size affects more than just the birth weight of individual piglets. Research has shown that there are serious welfare (Rutherford et al. 2013; Sorensen et al. 2016; Schmitt et al. 2019) and immune concerns (Oliviero et al. 2019) related to the remarkable increase in litter size. Large litter sizes have also been associated with increased pre-weaning piglet mortality (Peltoniemi et al. 2021).

Sow reproductive performance is a key metric for producers managing commercial herds. It is assessed for sows based on total born piglets and serves as a productivity and performance standard (Koketsu 2007). In successful breeding programs, the total number of piglets for each farrowing can surpass the number of functional teats in a sow; hence, the sow's functional teat number could serve as an impediment for such a larger litter. Piglet nursing has evolved to guarantee that each piglet requires one teat and to eliminate competition for resources within the litter. Some piglets born from large litters may not have a teat and will be seriously at risk of starvation to death. Therefore, raising additional piglets until weaning puts more demand on sows. When a batch of sows has more viable live-born piglets than functional teats, interventions are required to successfully nurture the greater number of piglets (Rutherford et al. 2013)

On commercial pig farms, a variety of management interventions are used to ensure that the greatest number of piglets are weaned. For instance, recommendations for split suckling (Peltoniemi et al. 2021; Arnaud et al. 2023), fostering measures

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(Deen and Bilkei 2004; Ward et al. 2020), using nurse sows (Alvasen et al. 2017; Alexopoulos et al. 2018), double nursing (Houben et al. 2017) and artificial rearing (De Vos et al. 2014; Novotni-Danko et al. 2015; Houben et al. 2017) have been reported. On many commercial pig farms, Large White and Landrace crossbreds are the most dominant hyperprolific breeds. The development of hyperprolific sows fits within the economic paradigm of weaning more piglets for economic gain. From the abovementioned strategies, the utilization of nurse sows becomes a more realistic natural way of handling large litters as opposed to artificial rearing.

FOSTERING AS A FOUNDATION FOR NURSE SOW MANAGEMENT

The genesis of the nurse-sow management system is derived from fostering events. Fostering is the practice of moving piglets from one sow to another in modern pig production to increase survival (Alexopoulos et al. 2018). This is often done when a sow gives birth to more piglets than she has functional teats. Fostering and the nurse sow system are related, and to understand the nurse sow system, one has to draw basic fundamental precepts from fostering.

The process of fostering entails a chronology of events. At the time of farrowing, when numerous piglets are born, it is crucial to place them on functional teats so that they can acquire individual teats and suckle, which is vital for survival. Colostrum intake and uptake, which provide piglet nutrition, passive immunity, and energy needed postpartum, determine the survival of piglets (Le Dividich et al. 2005; Devillers et al. 2007; 2011; Cabrera et al. 2012; Decaluwe et al. 2014; Declerck et al. 2016; Agbokounou et al. 2017). The amount of immunoglobulins in colostrum has been found to dramatically decrease within the initial 24 h (Klobasa et al. 1981), hence, to ensure survival, it is crucial that all piglets suckle colostrum before being fostered. Thus, consuming colostrum prior to being fostered becomes a very important first step to ensure piglet viability. The entire litter must receive mother's colostrum to get adequate immunity. Immunoglobulins in colostrum contribute to the development of immunological responses, and reinforce the protective layer of the intestinal wall (Rolinec et al. 2012). Furthermore, adequate consumption of colostrum has been associated with favourable effects on piglet post-weaning adaptability (Sola-Oriol and Gasa 2017). Despite the aforementioned advantages, it has been shown by Quesnel et al. (2012) and Decaluwe et al. (2013) that approximately 30% of hyperprolific sows do not produce enough colostrum to meet the needs of piglets. This presents an immediate challenge and therefore split suckling becomes a second step in ensuring piglet survival.

Split suckling permits a portion of the piglets to suckle first, and the remainder to suckle later in turns. Two groups are formed from the litter depending on size or vitality or age. First-born piglets with a full belly are removed from the udder and placed in a "tote"/bucket under a heat lamp for about 90–120 min (authors' observation). This gives the smaller, later-born piglets many opportunities to suckle without having to compete with their bigger littermates (Kirkden et al. 2013). Split suckling must occur as soon as feasible after farrowing to enhance colostrum absorption for the smallest/weakest piglets. Additionally, the smallest/weakest piglets are more susceptible to heat loss and hypothermia, due to their larger surface area to volume ratio and lower capacity to regulate body temperature (Zeng et al. 2019). Therefore, split suckling would guarantee that colostrum is distributed more evenly throughout the litter, decreasing litter weight variability and improving survival rates.

Piglet equilibration is the third step that takes place after colostrum intake. This is aimed at balancing the number of piglets with the number of functional teats on a sow. Although it is expected that every piglet should receive a functional teat, it is clear that some piglets will remain after equilibration owing to large litter sizes and restricted availability of functional teats. Finding a nurse sow for the remaining piglets, often known as fostering, is necessary. It should be noted that the nature and condition of the remaining piglets will determine the type of nurse sow to be selected. A sow that farrowed within four to eight days ago is selected as a foster sow to nurse the one-day-old piglets (Baxter et al. 2013). In this case, to care for one-day-old piglets, the foster sow must "abandon" her four- to eight-days-old piglets and move into the present farrowing house. This "abandonment" causes a new problem because the four- to eight-days-old "abandoned" piglets need a sow to raise

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them. Hence these four- to eight-days-old piglets are placed on a nurse sow that originally has been lactating for 21 days. As a result, the nurse sow system is a series of actions with fostering as its foundation.

NURSE SOW SELECTION AND ACCEPTANCE OF NURSED PIGLETS

Nurse sows are employed to raise more piglets. In sow herds that are extremely productive and have large litters, using nurse sows is a typical practice, with herd proportional numbers ranging between 11–33% (Bruun et al. 2016) or 10–15% (Bortolozzo et al. 2023).

According to Baxter et al. (2013), the nurse sow is a sow which has simply weaned a litter of piglets and subsequently was given other piglets to take care of within a single lactation phase. Similarly, Bruun et al. (2016) indicated that the sow is considered a nurse sow when she weans her own litter after a minimum of 21 days and afterwards she weans additional litter from an unrelated sow after another 21 days. Alvasen et al. (2017) defined the nurse sow as one that weans piglets in one farrowing house before moving to another to wean other piglets. Therefore, using nurse sows is seen as a natural way that allows piglets to continue suckling as opposed to moving them to an artificial piglet raising system commonly referred to as "Rescue Decks". Natural suckling is the main distinction between using nurse sows and artificial rearing. The two are the main methods of handling large litters in commercial pig systems, whereby in the former, piglets embrace social interactions with the sow. In cognitive science, offspring's early life experiences such as social interactions have been linked with providing enrichment for positive development of the brain, behavioural responses, and endocrine processes (Camerlink et al. 2018; Salazar et al. 2018; Lucas et al. 2023). Various studies have supported the fact that natural piglet suckling is beneficial as it is linked to favourable emotional experiences of piglets (Spinka 2006; Skok and Gerken 2016) witnessed through sow to piglet interactions (Hotzel et al. 2004; van Nieuwamerongen et al. 2014; Portele et al. 2019) that result in improved welfare (Bracke and Hopster 2006; Clouard et al. 2022) and it is linked to the favourable lifetime performance of piglets (Vanheukelom et al. 2012).

Selection of nurse sows is aimed at ensuring that the sows are recognized as parents for the nursed piglets. Given that herds contain gilts, sows and boars, research from the past and present has concentrated on gilt selection (Patterson and Foxcroft 2019; Faccin et al. 2022) and boar selection (Robinson and Buhr 2005; Safranski 2008). All these findings have provided pig producers with plenty of knowledge as standard guidelines. Gilts eventually mature into sows in herds, and it is important to remember that successful gilt selection is the foundation for good sow performance. However, the selection criteria used to choose the gilts do not suffice to enroll the same gilts in the nurse sow program.

It is imperative to focus on correct nurse sow selection for success in the nurse sow system. In herds, sows are not chosen at random to serve as nurse sows because random selection would compromise the desired predicted performance of piglets and sows. Studies on nurse sow selection have been localized in Denmark (Bruun et al. 2016; Sorensen et al. 2016), however, an increase in litter size justifying the use of nurse sows has been reported worldwide, including Australia (Alexopoulos et al. 2018), Sweden (Alvasen et al. 2017), The Netherlands (Houben et al. 2017), United States (Garrido-Mantilla et al. 2021), Ireland (Schmitt et al. 2019), and the Czech Republic (Pokorna et al. 2020). Notably, there are significant regional and farm disparities in how agricultural protocols are handled, which might mean that a one-fit design for all cannot be used. As a result, the choice of an appropriate nurse sow may depend on farm-established protocols and circumstances in the farrowing room.

The selection of a nurse sow involves certain aspects. Bruun et al. (2016) indicated that nurse sows are selected among sows in lactation. Lactation becomes a factor in the choice of a nurse sow because the stage of sow lactation affects the success of the nurse sow system. Nutritional milk composition changes from colostrum to whole milk during the lactation period (Klobasa et al. 1987; Curtasu et al. 2016) and the nutritional needs of piglets are determined by their age during lactation. Baxter et al. (2013) established that in both one- and two-step approaches, a sow weans her own piglets after piglets have been nursed for at least 21 days, and then she is given one-day-old piglets from another sow to nurse them for 21 days at least. In a two-step

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approach, two sows are used: the first sow weans her own biological piglets after 21 days, and then she receives a full litter from a sow known as the intermediate ("bumb") sow, which had been nursing her litter four to eight days after farrowing. Day one surplus newborn piglets from different litters are delivered to the intermediate sow after 6 h to 12 h of nursing from their original sows. Thus, throughout the entire process, the ideal chronological suckling period is interrupted by fluctuations in lactation days (see Figure 1).

According to Weber et al. (2009), the first and second parity sows can be selected as nurse sows because they have better body control while moving in the nursing crate, and due to their small teats they are more suited to small piglets. Furthermore, Weber et al. (2009) indicated that these young sows have lower mortality rates of piglets during their suckling than older sows nursing piglets of the same size. Using exclusively low parity sows as nurse sows may be limiting when the proportion of the first and second parity sows in the present farrowing cohort is lower than the number of nurse sows required. Koketsu et al. (2017) found that the first and second parity sows have good lifetime performance, therefore using them as nurse sows could be considered as "overexploitation". Sadly, sows with parities 4 and higher are considered old sows and are more susceptible to health problems and poor performance (Sasaki and Koketsu 2008), lowering their likelihood of choice as nurse sows. In a study conducted among pig farmers in Denmark, Sorensen et al. (2016) stated that farmers also considered the weaned number of piglets prior to receiving the nursed litter, number of functional teats, and sow body condition score as priority factors.

It is possible for a nurse sow to lose the body condition score (BCS) during extended lactation; therefore, it is advised to choose a nurse sow with good BCS. Sows with low BCS have a high risk of shoulder lesions (Zurbrigg 2006). Standard industry protocols indicate that nurse sows should be given an equal or lower number of nursed piglets compared to their weaned piglets. It is believed that each weaned piglet was sucking from a functional teat. This enables nursed piglets to continuously nurse from available functional teats (Sorensen et al. 2016). It has been observed that sows are likely to exhibit piglet-directed aggression towards alien piglets (Algers and Uvnas-Moberg 2007) followed by possible rejection (Bortolozzo et al. 2023). In order for the nursed piglets to be accepted more quickly, nurse sows with calmer behaviour may be a better choice. The health of a sow is crucial for the sow to perform its physiological functions. Piglet nursing is a physiological process that requires a sow to be in good health. Bruun et al. (2016) found that most Danish farmers selected nurse sows simply because those sows "looked better". There have been documented cases of nurse sows being used more than once during a single lactation period (Iida et al. 2019). In such a situation, the sow having

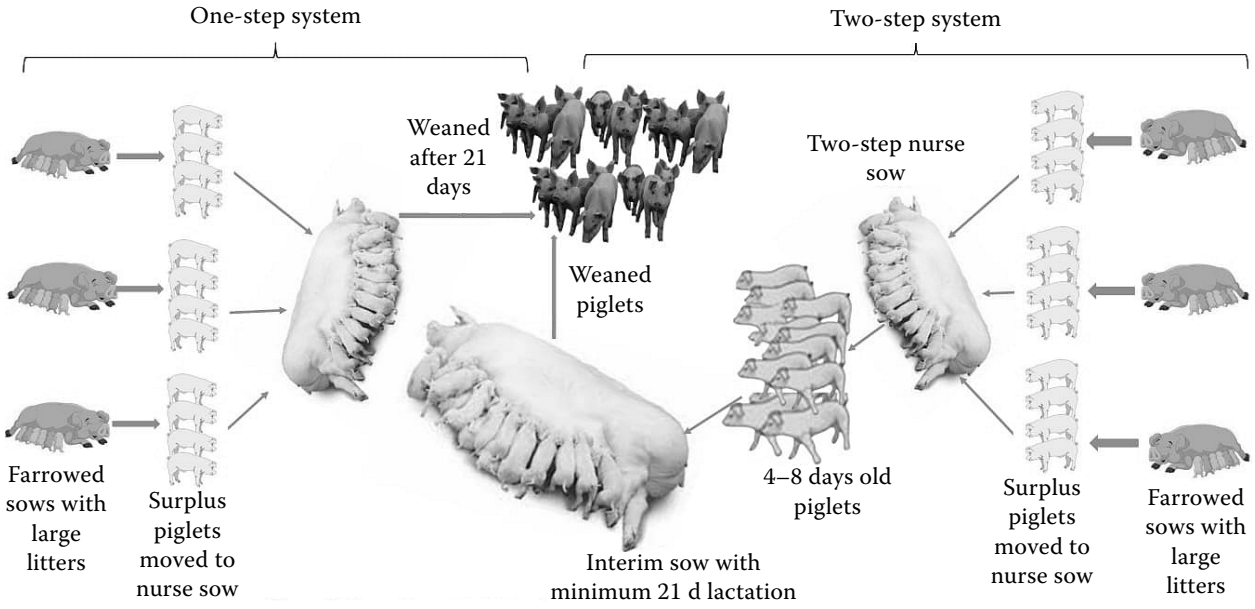

Figure 1. Illustration of 1-STEP and 2-STEP nurse sow system (as described by Baxter et al. 2013)

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been used as a nurse sow in the past may have contributed to her subsequent selection. Piglet crushing is the main cause of piglet pre-weaning mortality in pig production (Muns et al. 2016), and sows have been found to show some consistency in mortality among parities (Jarvis et al. 2005). Parities that show consistency in crushing piglets should be avoided when selecting nurse sows.

The condition of the sow's current litter may provide an insight into how well she has been nursing piglets. Strong, healthy, and viable piglets are attributed to her good mothering ability. Sows that effectively nursed their biological piglets could also do the same when given nursed piglets. According to Baxter et al. (2013) sows with fewer days of lactation are favoured for selection to nurse surplus one-day-old piglets. Small-sized piglets would be comfortable when nursed on a sow with small-sized teats (Weber et al. 2009) and with their similar age group (Schmitt et al. 2019).

Most farrowing rooms should have many active crates (with lactating sows) and a few non-active crates (open crates). Open crates in a current farrowing house are a strategy to accommodate any incoming nurse sows. There is a challenge when there are no open crates. Stockpersons should have to relocate a certain sow to create an open crate (authors' observation). This is mostly done to ensure that the weaning age of piglets remains uniform in the farrowing house. Weekly breeding targets consist of weaned sows and gilts to be bred, and are used to measure herd efficiency (Pettigrew et al. 1986). A weekly threshold exists for the number of weaned sows and gilts that can be bred on a farm. The number of nurse sows that remain in lactation could have an influence on this balance. Social interaction between nurse sow and adopted piglets is mostly witnessed at the udder during suckling. The nurse sow udder may be contaminated with the Influenza A Virus (IAV) (Lopez-Moreno et al. 2022), which can infect adopted piglets (Garrido-Mantilla et al. 2021). However, a stockperson can make trade-offs in all these factors based on the available potential nurse sows.

Factors to consider for nurse sow selection can be categorized as shown in Table 1.

Following selection, the nurse sow needs to be given piglets and show signs of acceptance. Mammals have olfactory cues that aid offspring recognition and acceptance (Horrell and Hodgson 1992a,b). As has been observed in domestic livestock, cows and goats recognize their young after birth by sniffing them, which helps them form the first mother-child maternal bond. As a result, smell plays a crucial role in mother-child acceptance, and nurse sows are no exception. In normal industrial settings, the ideal selected nurse sow is placed in a crate, and then already identified nursed piglets are given to her. It has been reported that nurse sows are likely to reject incoming piglets (Kobek-Kjeldager et al. 2020; Bortolozzo et al. 2023) because they smell different from their own biological piglets; hence, there is a need to mask the smell of foreign piglets to aid in faster acceptance. Scent masking aimed at nurse offspring acceptance has been reported in domestic animals, such as cattle (Pearson et al. 2019) and sheep (Dwyer 2014). The use of scent masking techniques in sows may be hampered by sow behavioural traits that are selected for docility and calmness (Norris et al. 2014), however farm tried methods, such as mixing the sow's own piglets with nursed piglets, are a possibility. In this case, some of the sow's own piglets are mixed with nursed piglets for a short

Table 1. Summary of factors to consider when selecting a nurse sow

Category	Factors	References
Sow related	Lactation, Parity, Body condition score, Number of functional teats, Size of the teats, Temperament/ aggressiveness, Sow general health, Previous nurse sow experience, previous history of crushing piglets	Bruun et al. (2016); Weber et al. (2009); Zurbrigg (2006); Sorensen et al. (2016); Algers and Uvnas-Moberg (2007); Iida et al. (2019); Jarvis et al. (2005)
Piglet related	Current litter size, Current litter age, Current litter health status, Nurse litter size, Nurse litter age, Nurse litter health status	Sorensen et al. (2016); Baxter et al. (2013); Weber et al. (2009); Schmitt et al. (2019)
Management related	Availability of open crates, Breed targets, Biosecurity concerns	Pettigrew et al. (1986); Lopez-Moreno et al. (2022); Garrido-Mantilla et al. (2021)

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time, and later they are removed to allow the nursed piglets to acquire the smell of the sow's piglets in an effort to disguise the sow. Additionally, baby pig powder is used to camouflage the smell of the environment by dusting piglets with it immediately they are introduced to the nurse sow (authors' observations). However, despite their intent to promote quicker acceptance, these protocols lack scientific support and scientific exploration is warranted. Failure to immediately accept foreign piglets to nurse has resulted in longer waiting times for nursed piglets to experience their first suckling. For instance, an average waiting time of 4.7 h was reported by Kobek-Kjeldager et al. (2020). The piglet's goal is to gain faster acceptance for immediate suckling to maximize its nutritional potential; hence, longer waiting times are undesirable.

IMPACTS ASSOCIATED WITH NURSE SOW MANAGEMENT SYSTEM

Selected impacts on nurse sows

The sow's annual weaned piglets and lifetime performance are performance benchmarks used to determine the productivity potential of pig herds (Koketsu et al. 2017). When piglets weaned per sow/year are used as the standard, nurse sows nursing double litters depict significant numbers becoming economically advantageous. Furthermore, nurse sows nursing two litters have ample time for the uterus to involute before their next pregnancy (Rezac et al. 2023). However, prolonged lactation in nurse sows has notable negative impacts. Most profoundly, the well-being of the sow is compromised, especially due to the loss of body reserves reflected in backfat thickness from high milk production (Koketsu et al. 2017). The amount of energy required for reproduction is indicated by the backfat thickness (Thiengpimol et al. 2022), and sows that extensively deplete these reserves show poor reproduction thereafter (Vinsky et al. 2006). Continuing to nurse piglets puts pressure on the nurse sow and she may mobilize much of her body reserves, particularly in the event of insufficient lactational resources. This leads to the decreased backfat thickness in the first two weeks, as supported by (Strathe et al. 2017).

However, Schmitt et al. (2019) contradicted Strathe et al. (2017) research by finding no variation in the backfat decrease among sows using the one-step nurse sow approach with total nursing time of 7.9 weeks.

Alvasen et al. (2017) indicated that prolonged lactation deteriorates the physical condition of nurse sows, resulting in leg ulcers and teat damage. According to Baxter et al. (2013), additional confinement in farrowing crates for nurse sows under restraint for up to seven weeks caused welfare issues such as foot, shoulder, and leg issues. This was supported by Jensen (2009), who found that the long-term confinement could have locomotor effects; in particular, frequent or extended lying down might cause shoulder lesions.

Furthermore, a study conducted in Denmark on commercial pig farms employing the nurse sow system showed that sows reared as nurse sows had more wounds on their udders and bursa on their legs than did non-nurse sows (Sorensen et al. 2016). It is more common for nurse sows to sustain udder as well as teat injuries (Rutherford et al. 2013), especially when piglets pick up a fight at the udder competing for teats.

In general, management practices that require separating sows and litter have the potential to cause stress. Nurse sows may be under enhanced stress, which is worsened by the strain to produce an adequate quantity and quality of milk throughout the prolonged lactation period. Cronin et al. (1991) reported elevated amounts of the stress hormone cortisol in the saliva of sows kept for more than 28 days in pens.

However, Amdi et al. (2017) revealed the absence of cortisol levels in nurse sows, which is in direct opposition to this conclusion. Due to the lengthy confinement, nurse sows, like other animals, exhibit atypical stereotypical behaviours (Lawrence and Terlouw 1993) such as frustration which was observed in confined gestating sows in a study by Barnett et al. (2001).

Selected impacts on nursed piglets

The main goal of the nurse sow method is to maximize pre-weaning survival while also benefiting the piglets. Similar to this, using nurse sows significantly increases piglet average daily gain and weight at weaning (Rezac et al. 2023), it is related to improved gut immunity in piglets (Berkeveld et al. 2009) and boosts the overall worth of low birth

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weight piglets (Craig et al. 2020). However, possible negative effects could be observed on piglet performance. For instance, Kobek-Kjeldager et al. (2020) found that nursed piglets grew at a slower rate than non-nursed piglets of the same size because the teat order was unstable, which forced competition and lowered weaning weights. Because large and small piglets frequently compete for the udder, their size may increase competition. On the day the nursed litter is created, a variety of piglets are combined to produce a litter based on size, age, and weight. According to De Passille et al. (1988), piglet suckling behaviour has evolved to guarantee that each piglet claims a distinct teat and maintains fidelity during suckling to prevent litter rivalry. However, when a nursed litter is put on a nurse sow, piglets must rearrange themselves at the new udder to establish a teat order.

This reorganization, which is witnessed with aggression during the initial hours, often results in litter disputes eventually leading to fighting (Arnaud et al. 2023). Fighting prevents piglets from getting enough time and an opportunity to nurse because attention is diverted from suckling to the establishment of a litter hierarchy. Piglets with low weights may not be able to fight for the teat acquisition as their larger counterparts, which causes them to suffer more (Milligan et al. 2001). Piglets that do not win the competition have slower pre-weaning growth and are more likely to die during the first stages of lactation (Rutherford et al. 2013). The unfavourable growth performance has been found to proceed beyond the lactation period affecting the nursery health (Kirkwood et al. 2021). Fighting makes suckling sessions less efficient resulting in difficulty for piglets to grow steadily. Therefore, fighting should be avoided at all costs through the right selection of the nurse sow and nursed piglets.

As maternal backgrounds and bonding are distinct among litters, piglets are more distressed when taken away from their biological sow to a new sow (Weary et al. 1999; Cheng et al. 2023). Belly nosing and tail biting are common behavioural indicators of stress in a nurse-produced litter (Schmitt et al. 2019), which may be related to social instability in the litter (Rzezniczek et al. 2015), resulting to negative consequences. It may take several hours for nursed piglets to nurse, however, *ad libitum* and timely milk suckling is essential for the piglets' healthy growth and immunological status during lactation.

Selected impacts of management

Breed-to-wean systems of pig production employ the "all-in-all-out" management scenario aimed at controlling the spread of diseases and enhancing biosecurity. Threats to biosecurity are real, especially when there is a continuous movement of sows and piglets from various farrowing houses to others. The use of nurse sows breaks the biosecurity protocol in farrowing houses (Calderon Diaz et al. 2017), as clinical diseases could rapidly spread from the incoming adult animals to the vulnerable young stock. Another problem is that nurse sows stay longer in farrowing crates than planned, resulting in blocking the farrowing pens (Rezac et al. 2023). This obstructs the pig flow since the nurse sow's farrowing crate will not be ready for fresh litter for another two to three weeks (Kirkwood et al. 2021). Obstruction of this pig flow is also witnessed at gestation houses, as using nurse sows alters the expected numbers of weaned sows that could have been served, interfering with farm managers' weekly breeding targets (authors' observation). Despite all the aforementioned flaws, using nurse sows to maximize pre-weaning survival is a promising management strategy.

CONCLUSIONS

The employment of the nurse sow system emerges as a key component in the overall solution of managing increased litter sizes in conventional pig production. A crucial sign of the system's success is the adherence to the step-by-step procedures outlined in this review from the initial point of realizing the need to use nurse sows. As this review has outlined the benefits and drawbacks of using nurse sows, this does not restrain producers from continuing to use it. Managing large liters on a large scale in intensive commercial pig systems can only be done either by using the nurse sows or by artificial rearing. There is a lack of a comparative study envisioning both methods that can explore their effectiveness and viability from inception to end. The results of such a comparative study can provide thorough understanding that could allow producers to choose between the two processes with sufficient knowledge. However, it should be noted that adopting the best management protocol is an integration of many factors, including feasibility and expected economic

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returns. As a result, this review has advanced the scientific understanding of nurse sows that is necessary for producers to make wise judgements.

Future perspectives

A breeding objective in pig production for hyperprolificacy may not cease soon, and hence, the economic paradigm driving the use of hyperprolific sows (HPS) is expected to continue. Nurse sows reflect a more natural way of handling large litters from HPS as compared to artificial piglet rearing. The nurse sow system may be a more cost-effective way to satisfy growing global concerns about the implementation of more sustainable farming systems that permit animals to display more natural behaviours in natural habitats. Furthermore, modifying housing and buying milk substitutes, which are not necessary in the nurse sow system, comes with a significant financial investment in artificial piglet rearing. Therefore, future pig production systems will be driven by the reduced cost of production in a more sustainable way.

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Conflict of interest

The authors declare no conflict of interest.

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