

Sow and piglet behaviour during lactation: A review focusing on selected behaviour manifested by foster sows and their fostered piglets

Joab Malanda Osotsi^{1,2}, Yogi Sidik Prasojo^{3*}, Putri Kusuma Astuti^{2,3,4}, Mequanint Gashew^{1,2}, Peter Balogh⁵, Jozsef Ratky⁶, and Gabriella Novotni-Danko¹

¹University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, 4032 Debrecen, Hungary

²University of Debrecen, Doctoral School of Animal Science, 4032 Debrecen, Hungary

³Faculty of Animal Science, Universitas Gadjah Mada, 55281 Yogyakarta, Indonesia

⁴Centre for Agricultural Genomics and Biotechnology, University of Debrecen, 4032 Debrecen, Hungary

⁵Faculty of Economics and Business, University of Debrecen, 4032 Debrecen, Hungary

⁶University of Veterinary Medicine, Budapest, Hungary

Abstract. Foster (F) sows are used to nurse piglets from other sows. Nurse (N) sows are used to nurse other piglets after weaning their own piglets during lactation. Sows nursing non-biological piglets can reject or attack unfamiliar piglets. Similarly, N/F sows could fail to recognize the adopted piglets, which may result in delayed or denied suckling. Behaviours such as rejection, aggression, and failure to suckle pose both physical and nutritional challenges to the fostered piglets. Therefore, after collating the literature, this review was able to establish the following: nurse or foster sows showed antagonistic behaviour towards adopted piglets through aggression and discrimination. Similarly, N/F sows terminated nursing bouts more frequently than non-N/non-F sows. Most N/F piglets upon encountering N/F sows showed wandering squealing syndrome with escape attempts. Nurse/foster piglets exhibited more post-teat massage behaviour, a sign of 'begging for more milk.' Resident piglets frequently attacked fostered piglets through fighting. Management of large litters in pig production entails the use of N/F sows, and the knowledge in this review could help in improving N/F sow production systems, especially on lactational behaviour. Explanations of possible interventions that are likely to reduce negative behaviours among foster sows and their piglets has been given.

1 Introduction

Foster (F) sows are sows that raise piglets from other sows according to fostering procedure. Fostering is a management protocol aimed at improving the chances of other piglets receiving adequate nutrition and thriving. In practice, this entails relocating some or all piglets from the birth sow to a foster sow or transferring piglets between sows based on the udder's physical qualities, as well as the piglets' size, vigor, and gender [1-2]. As a result, it is connected to the piglet's first twenty-four hours of life. Therefore, it is typical for F sows to raise a mixed litter of their own and adopted piglets. Nurse (N) sows are sows that wean their litter and are used to nurse other piglets. The use of N sows is referred to as 'back fostering' [3]. Under this protocol, sows rear a completely different set of piglets from their own. This protocol is commonly used for handling piglets after 24 hours of life. Nurse sows aid in improving pre-weaning survival by boosting the overall value of low-birth-weight piglets. Under typical

conditions, N/F litters can be created in one of three ways: either all the piglets are from the donor sow, the piglets are mixed together to take a homogenous litter, or the resident piglets are combined with the adoptive piglets. Rearing of non-biological piglets may result in the sows exhibiting distinct maternal behaviours such as rejection and delayed or failed nursing [4-7]. Social interactions between sows and piglets during lactation are among the most researched behavioural expressions [8-11]. Sow-piglet interactions play a critical role in maximizing piglet growth and survival [10, 12] as well as their future welfare [13-14]. Similarly, early interactions in piglets, especially during nursing, have been found to be associated with the development of positive life skills [15-16].

Large litters are common in commercial farms, and when addressing the issue of managing large litters, it's important to consider fostering [17] and nursing [18-19] as potential solutions. However, it's crucial to acknowledge the behavioural challenges that can arise,

* Corresponding author: yogi.sidik.p@ugm.ac.id

as they can pose significant obstacles to effective management protocols. The significance of this study was drawn from the fact that, understanding foster sows behaviour interactions with piglets during lactation allows farmers to create environments that facilitate successful nursing and bonding between sows and piglets. Successful nursing sessions can enhance the growth of piglets and improve their nutritional welfare and survival. Enhanced survival rates could directly translate into higher productivity and profitability for farms as more healthy piglets reach weaning age and become economically viable. Knowledge of behavioural interactions can help implement strategies that minimize aggression and rejection. When sows accept foster piglets faster, the need for supplementary care like 'fall behind management' for undernourished piglets decreases. Successful nursing behaviour improves pig welfare; however, the opposite is true for increased stress levels among both sows and piglets. For instance, rejection of foster piglets denies them nutrition, which can adversely affect their health and overall welfare. Considering this, this review aimed to examine the maternal behaviour of foster sows during lactation and their fostered piglets. Particular attention was paid to aspects of general suckling behaviour, sow aggression and rejection, wandering and squealing syndrome, naso-naso contact, and fighting among piglets.

2 Overview of suckling behaviour

Suckling is the most depicted and early social interaction behaviour between sows and piglets during lactation [20-22], and the quality of suckling indicates the sow's willingness to care for the litter [23]. Like many other mammals, the natural instinctive behaviour is that the sow nurses while lying down. Thus, during the whole cascade process of suckling, the sow's initial behaviour is to lie down. Lying down improves the ability of piglets to access the udder [24]. A sow's typical nursing posture involves lying on one side to expose both rows of teats, raising her upper legs, and straightening the forelegs to provide the piglet's access to the anterior teats. Typically, this behaviour is accompanied by intermittent grunts from the sows which indicate contentment, and are often a sign that the sow is relaxed and comfortable during nursing.

2.1 Lying down

Sows in lactation usually adopt a lateral lying position to expose all their udder teats to piglets for nursing. Foster sows showed significantly lower lateral lying [4, 25]. This is a common signal, primarily observed in sows approaching the weaning phase, such that they may not be accustomed to suckling as they were at the start of lactation. Furthermore, foster sows had less udder exposure at suckling [4, 26]. Foster sows that had been nursing for a longer time may have developed a desire to wean piglets and, thus, be less inclined to permit suckling. The same authors observed that instead of lateral laying during nursing, N sows adopted a dog-

sitting posture. The behaviour of sows portraying dog sitting position during nursing is not conducive for teat exposure. In addition, unusual lying down, such as lying on the sternum, can have a major negative impact on nursing, which manifests as a failure to rotate the udder. As a result, lactating sows lying down indicate how good they are in coordinating nursing with the piglets.

2.2 Piglet distribution to the udder

There is seldom instant suckling once the sow has laid down; instead, it may take some time. Typically, piglets would line up at the sow's udder in an established pattern known as "teat order" [27]. Teat order is a form of established hierarchy that determines which piglet will nurse from which sow teat. Selecting piglets for exchange that already had a 'preferred teat' from their biological sow and fostering them among other resident piglets was part of the methodology used in a study by Horrel [28]. Foster piglets would try to find their favorite teat on the foster sow, and if they couldn't, they would fight more fiercely. Early life experiences in pigs have been linked to memory creation [29]. The memory of a preferred teat created by the foster piglet linkers with it even when fostered to another sow, resulting in competition for their preferred teat. Fostered piglets in mixed litter had difficulty in accessing their preferred teat [30]. Resident piglets already knew their dam, preferred teats, and littermates unlike adopted piglets. Such 'home advantage' for resident piglets would give them an upper hand. Failure or inability to take a rightful position at the udder at the start of suckling would be disadvantageous to fostered piglets (Figure 1).



Fig 1. A piglet that has just missed a rightful position at the udder. It is spotted wandering around when the rest of the piglets are actively engaged in suckling (seen through the alertness of their ears, teat in the mouth, and eyes open) (author observation). Picture: Courtesy of a commercial Farm, Hungary.

2.3 Actual suckling

Natural suckling in pigs typically occurs approximately every hour [20]. Actual suckling behaviour normally involves the following steps: initiation, latency, milk let-down, and termination.

2.3.1 Initiation of suckling

The process of initiating suckling is an innate and natural behaviour [31] that depicts the evolution of mother–infant feeding in mammals [32]. Piglets possess a strong instinct to suckle from birth, ensuring they seek nourishment immediately after birth. Suckling behaviour is crucial for supporting the early life of piglets [33] and influences piglet's future behaviour [34–35]. Nurse sows were observed to largely prevent a successful let-down despite having a good initiation [26], suggesting disruptions during suckling and the presence of foreign piglets within the litter.

Naturally, piglet initiation of suckling begins with an initial massage where piglets nuzzle and cling to teats. Schmitt et al [36] found no differences between fostered and control piglets at the initiation of suckling. Successful initiation of suckling helps establish a bond between the foster sow and adopted piglets. This bond is essential for fostering maternal behaviour and ensuring that piglets receive adequate care and nutrition. However, this bonding process can be hindered if either the sow or piglets are reluctant to initiate suckling. Furthermore, because of nervousness in the newly formed litter, fostered piglets may be less likely to reach the udder and initiate suckling than resident piglets. This can stem from stress or fear, which impacts their ability to engage in normal behaviours, such as teat massage. While sows would initiate nursing from the point of voluntary manifestation of the instinctive mother to the child's need to feed the young, piglets typically initiate nursing from the perspective of being hungry.

2.3.2 Latency, milk let-down, and active suckling

The term "latency" in relation to pig suckling refers to the time interval that sows take after the pre-massage period to manifest a milk let-down. Foster sows had higher latency (implying a longer time to have a let-down) as compared to control sows [25, 28]. Foster sows may experience increased stress when nursing piglets that are not their own. This stress can affect hormonal responses, delaying the release of oxytocin, which is crucial for milk let-down. In contrast, control sows, who are nursing their own piglets, may be typically more relaxed and comfortable, facilitating quicker let-down. Additionally, control sows have a natural bond with their own piglets, which may trigger a faster let-down. Foster sows lacking this immediate bond may take longer to initiate the same physiological response. Additional research on latency may yield significant information regarding the effectiveness of pre-massage. Research on latency can also shed light on how quickly a sow is able to allow milk let down, which is a test of the sow's aptitude to suckle.

Milk let-down is the release of milk from teat cisterns to the mammary glands for suckling and can be viewed as a landmark event in the suckling process. Following latency, milk ejection occurs and lasts for approximately 10–20 seconds [37]. There was fewer milk let-down in sows with fostered piglets than in control sows [4, 6]. This reluctance to suckle was due to the presence of alien piglets in the litter. A practical solution could be mixing sows own piglets and adopted piglets for faster recognition and acceptance of the litter. Faster acceptance of the litter would result in an easier willingness of the foster sow to exude suckling. It has been shown that sows differentiate between their own and foreign piglets based on olfactory cues [38]. This can enable them to discriminate between their own and alien piglets. However, after mixing, the smell can quickly fade away, but adopted piglets will remain adopted. Further research into the behavioural psychology of sows may investigate the degree to which a sow accepts an adopted piglet until weaning.

Active suckling occurs when piglets suckle vigorously for a short period without pausing to move or giving a teat massage. Incidences of missing nursing bouts have been observed, especially in foster litters [30]. Resident piglets become accustomed to their mothers and surroundings, whereas the adopted piglets could focus on exploring their new environments, hence missing the initial suckling periods. Missing nursing is also exacerbated when F piglets are older than the other piglets, and recommendations for cross-fostering within the first 24 h have been made [39–40]. This is because day 1 piglets have not yet defined their teat order at the time of fostering, which reduces fighting and, consequently, fewer missed nursing bouts. Nursing frequency plays a crucial role in adjusting the milk output [41]. There is a negative correlation between the frequency of nursing and competition at the udder [42], indicating that as competition increases, less successful nursing frequencies are observed. When a nurse or foster piglet's preferred teat is already taken, it may result in more failed nursing attempts, less attendance during nursing sessions, and increased fighting. Udder fighting is stressful for sows. The hormone cortisol is used for assessing stress, and according to a study by Baxter et al. [43], sows with lower cortisol levels experienced more successful nursing sessions and more sow-piglet interaction than sows with higher cortisol levels.

There are various schools of thought regarding why the final massage occurs after milk let down. This behaviour is associated with 'needy' piglets who express a form of dissatisfaction or still hungrier [44] (Figure 2) or the behaviour is associated with regulating milk transfer [45]. Jensen et al. [46] believe that the behaviour is associated with an increase in total milk production because piglets that engage in post-massage on occasion might encourage the sow to give them 'extra milk'. Fostered piglets were observed massaging the udders for up to 15 min after the end of milk let-down [36]. This behaviour was not observed in the control litters; however, the explanation for this behaviour was that it might be connected to the stimulation of future milk production.



Fig 2. A piglet displaying post-massage behaviour. Spotted actively massaging the udder in solitude while the other piglets are seen relaxing (author observation). Picture: Courtesy of a commercial Farm, Hungary.

2.3.3 Termination of suckling

Termination of nursing is mostly related to the end of successful nursing. Nevertheless, nursing can still be terminated prematurely (unsuccessful nursing) due to no milk let down by the sow. Nursing can be terminated by either sows or piglets. The sow terminates nursing when she suddenly or purposefully wakes up, either in response to a nearby stimulus or in response to no stimulus at all. Likewise, a sow can terminate nursing through deliberate obstruction of the teats by lying on her sternum (an act of refusal to suckle). Frequent standing with alertness was noticed when foster sows were uncomfortable with their new litter (author observation). Nurse sows displaced piglets and woke up, particularly in the treatment groups during the fourth week of lactation [26]. Sows' milk yield decreases with lactation length; nurse sows at 4 weeks into lactation would either experience a decrease in milk production or the stress of nursing for an extended period. Piglet's reorganization at the udder results in disputes that cause physical injuries. Foster litters were more likely to sustain carpal abrasions than non-F litters [47]. Similarly, Zanin et al. [48] observed that facial and joint lesions were more frequently observed in piglets that commingled with non-littermates than in piglets that remained intact. A connection between bodily lesions and suckling was made by Lohmeier et al. [22] sows that had litters with a high percentage of face lesions also had more frequent terminations of nursing. Termination by piglets under normal circumstances could mean that the piglets choose to leave the udder once the let-down is over. Piglets still attached to the udder engaging in post-teat massage could be seen as a sign of dissatisfaction and therefore "begging" for more milk [49]. Research on the termination of suckling by piglets is an intriguing area of study, which may yield important insights into whether termination signifies satisfaction or is simply related to the fact that there is

no longer any milk to be received, thereby negating the desire to continue nursing.

3 Vocalisations during suckling

Sow vocalizations can convey a range of emotional states, including those associated with hunger, heat discomfort, mating, farrowing, nursing, isolation, or fear. According to Olczak et al. [50] vocalization is a major means of communication for farm animals, and the way a dam communicates with her young is of particular significance. Specifically, sows grunt to signal the piglets when it is time to begin nursing. Foster sows were seen to discriminate against adopted piglets in the early days of adoption [51]. However, it is unclear whether this discrimination extends to the point where the sows are unwilling to vocalize to call the adopted piglets to nurse. Examining the relationship between vocalizations and the type of litter the sow is nursing, whether biological or adopted, may provide valuable information.

Piglets vocalize to express various emotional states. Piglets under foster sows may vocalize to cope with being taken from their mother [36]. This behaviour is believed to be linked to separation from the biological mother rather than being motivated by hunger. Schon et al. [52] found a correlation between the frequency and intensity of vocalizations with the severity of a situation. For example, high-pitched vocalisations are common in unfavourable situations, where piglets experience pain, such as during castration, iron injection, tail docking, or tagging. Low-pitched vocalisations such as grunts are more common in pleasant and neutral contexts such as suckling. Vocalisations can also be heard at the udder during teat competition. The intense udder rivalry between foster piglets always results in high-pitched vocalizations during the contest to re-establish the teat order. Ungulate young use suckling strategies to compete for colostrum and milk from their mother. Udder rivalry is when piglets compete directly for milk by ensuring that they have a teat in the mouth at the time

of milk let-down or compete indirectly for milk production by massaging the teats that they frequently utilize [53]. These tactics show how selection that promotes inclusive fitness and offspring selfishness have evolved together in pigs [54]. Additionally, piglets may vocalise during lactation for a variety of other reasons, such as being crushed by their mother, getting into a fight with one another, or experiencing an obstructed teat. In each case, the sow may respond to the vocalisation in an attempt to resolve the issue by standing up to avoid crushing or shifting the udder to expose the teats (author observation). Sows differed in how quickly they responded to vocalisations from their own litter compared to nurse piglets [43]. The sow's inherent tendency to be more concerned about the well-being of her own piglets than that of other piglets could have contributed to this discrepancy. This finding contradicts that of Collarini et al. [55] who observed that sows responded and reacted to vocalizations of piglets from other litters. Piglet vocalization acted as a distress signal, sounding an alarm to the sows that enabled them to enact a behavioural response. In mammals, auditory cues in young animals can offer clear and consistent indicators of their emotional condition, which might draw the attention of their mothers and cause a quick response [56-57]. Mixing of piglets could result in the sows being unable to distinguish between the cries of their own piglets and those of the foreign piglets [58].

4 Immediate behaviour seen after creating nurse or foster litter

4.1 By the sows

Normally, sows would identify and accept foster piglets before nursing them. This identification is seen through the naso-naso contacts [59-61] when sows sniff the 'new' piglets. Because alien piglets smell differently from their own biological piglets, it has been observed that sows are likely to display piglet-directed aggression towards alien piglets [5, 62]. This aggression may be followed by rejection [7]. Foster sows exhibited increased aggressive behaviours, virtually entirely aimed towards fostered piglets [4, 27]. These behaviours included snapping, shoving, and rapid fast biting movements. Kobek-Kjeldager et al. [6] observed a "unique" kind of discrimination when a nurse sow completely refused to let down milk to the foreign litter (seen within 24 hours of encounter). Eventually, when its litter was brought back, the sow let down the milk within 10 min. The ability of foster sows to distinguish between their biological piglets and fostered piglets, as well as the degree of aggression shown towards fostered piglets hinders successful nursing. Sows display very little or no aggression toward fostered piglets if fostering is performed up to 48h following parturition [63]. Moreover, the lack of aggression may result from the universal maternal instinct of care and affection, which compels the F sow to accept adopted piglets. Furthermore, what sets mammals apart from other creatures is that, they have evolved to give birth and then provide a source of nutrition for their infants which is

essential for growth and subsequent diversification [32]. Typically, aggression ceases soon after fostering is complete. However, if sows are continuously nursed or fostered during the lactation period, they may become unsettled because of continuous disruptions and interactions with foreign piglets.

4.2 By the piglets

4.2.1 Wandering squealing syndrome with escape attempts

Wandering Squealing Syndrome [28], is a notable behaviour when foster piglets are transferred to foster sows. This is when foster piglets exhibit restless movements and vocalize as signs of distress or discomfort. First, wandering is due to piglets' desire to investigate their new surroundings, the new mom sow, and their new littermates. Heim et al. [30] found that foster piglets lost more nursing bouts on day one than did resident piglets because they were busy exploring. Active engagement in pen and pen mate exploration would deny piglets the opportunity to nurse. Second, unlike resident piglets, fostered piglets would feel inferior to their litter mates and emit vocal sounds seen as "calling their own mom." In natural circumstances, when young ones are in distress they will vocalize to get the attention of their mother. Piglets fostered beyond two days vocalized more than piglets fostered earlier [64], suggesting that as piglets grow older, their mother-child bonding becomes stronger, and they might experience a strong desire to call their mother back. Third, foster piglets try to escape from a new pen [64-65]. Piglets try to escape to reunite with their former littermates or simply express a form of distress due to an unfamiliar environment.

4.2.2 Naso-naso contacts

Piglets are typically grouped together to form foster litters. Grouping ensures naso-naso interactions as a way of socializing for them to communicate [10] or simply attempts to investigate their littermates [66-67]. Since most social groupings would resist the entry of non-residents, resident piglets might feel compelled to investigate newcomers. Sniffing each other can be perceived as a precursor to fighting or eventual play. In a study by Clarkson et al. [68] non-F piglets initiated more play behaviours post-farrowing than piglets fostered in the litter, and as such, fostered piglets remained isolated for the first few weeks of life.

4.2.3 Fighting

Piglets fight among themselves as a form of sibling rivalry due to resource competition, establishing dominance, or stressful conditions. Fighting is a complex behaviour that is important immediately after birth to obtain a sufficient amount of colostrum and is seen as a means of establishing social order, which manifests itself as teat order (also suckling order). As a result, piglet fighting occurs at the udder when two or

more piglets attempt to suckle from the same teat, bite, or push each other with their heads or shoulders [6, 69]. Fighting can also be observed away from the udder among littermates and non-littermates. Piglet fights can begin with a choreographed examination of the opponent before engaging [29], or a surprise assault through biting [9]. Nurse piglets fought more than non-N piglets [27, 70]. As a result, foster piglets lost weight and missed more nursing bouts. Other reports of fighting for teats have been reported, particularly in nurse litters after the nurse litter was formed [6]. According to Pajzlar and Skok [2], the suckling stability or teat fidelity degree determines how well piglets integrate into their new environment. For this reason, foster piglets fought to re-establish the teat order.

There is more to fighting than just competition for a teat. Fostered piglets fought for their original sow's "preferred teat" and became less willing to participate in suckling sessions when they missed it [29]. Udder fights can be fierce in the beginning, but if a piglet loses or fails to possess their desired teat, they may have to give up and suckle any available teat to live. According to the hierarchy of livestock needs, meeting the demands essential for survival comes first. Therefore, battles to get a "special teat" might not be worth the time and effort invested in. Consequently, such fights could fade away, suggesting that teat conflicts are usually resolved over time [71]. Additionally, when N sows were selected (after 21d lactation) and given 1d old piglets, there was more fighting at the udder than when N sows were selected (after 14 d lactation) and given seven-day-old nurse piglets [40]. Since in the former, sows are far beyond in their lactation, it is possible that their milk production has decreased. This leaves piglets with little

milk and increases the likelihood of fights. It could also be that 1d old piglets have not yet established the teat order. In the same way, piglets that exhibit intense udder competition may cause stress to the sow and affect her milk production.

There may also be fights away from the udder. Fighting at locations other than the udder can be a play behaviour or a carry-over anger from the udder experience. It is interesting to note that resident piglets were not only aggressors in the crate, but also got into more fights with adopted piglets than with other resident piglets [70]. Aggression of resident piglets towards non-residents has also been reported [5]. Animals primarily tend to stay and guard their social groups and will engage in violent combat if they see or interact with an outsider. In a study by Kutzer et al. [72] piglets under control (that had no socialization with non-littermates at the time of lactation) showed significant antagonistic behaviour (biting and fighting) within four days of weaning. This was evidenced by the greater number and more severe skin lesions. Piglets from fostered litters fought less than control piglets during their first two days in the nursery and tended to have fewer skin lesions [73]. Socialization before weaning enables piglets to know each other, and this could help to tame the degree of fighting that occurs after weaning. Co-mingling among non-littermates during nursing decreased the degree of hostility that piglets encountered following weaning [74-75]. Fighting among piglets during lactation can have detrimental effects, such as injuries to the sows' teats and piglets themselves [52, 76], reduced weight gain [77] and decreased milk let-down [8].

Table 1: Summary of major highlighted behaviour by foster sows

Behaviour	The main theme	Sample size	Genetics of sows	Reference
Rejection	Cross-fostering on pre-weaning behaviour	27 litters	Crossbreeds	[4]
	Managing large litters using nurse sows	20 litters	Landrace x Yorkshire	[6]
Discrimination/Aggression	Managing large litters using nurse sows	20 litters	Landrace x Yorkshire	[6]
	Recognition of piglets by sows in early post-partum period	20 litters	Landrace x Yorkshire	[38]
Frequent termination of suckling	Nurse sow strategies in pigs (sow consequences)	47 litters	Large White x Landrace	[26]
	Suckling behaviour of piglets	248 litters	Large White x Landrace	[22]

Table 2: Summary of major highlighted behaviour by fostered piglets

Behaviour	The main theme	Sample size	Genetics of sows	Reference
Wandering squealing syndrome with escape attempts	Behaviour of fostering	24 litters	Large White x Landrace	[28]
	Cross-fostering and pre-weaning behavior	39 litters	Large White x Landrace	[30]

		24 litters	Large White	[64]
	Fostering in swine	47 litters	Large White x Landrace	[36]
	Nurse sow strategies pigs (piglet consequences)			
Post teat massage	Nurse sow strategies pigs (piglet consequences)	47 litters	Large White x Landrace	[36]
Fighting	Behaviour of fostering	24 litters	Large White x Landrace	[28]
	Nurse sow strategies pigs (piglet consequences)	47 litters	Large White x Landrace	[36]
	Managing large litters using nurse sows	20 litters	Landrace x Yorkshire	[6]
	Cross-suckling and associated behaviour in piglets and sows	18 litters	Danish Landrace x Yorkshire	[70]
	Contacts between littermates and non-litter mate piglets	113 litters	German Large White x Landrace	[72]
	Fostering smaller and older piglets	20 litters	Landrace x Large White, Pietrain	[2]

5 Practical applications of the findings

The antagonistic behaviour of foster sows towards adopted piglets suggests that careful selection of foster sows is essential. Identifying and utilizing sows with a calm temperament for fostering can minimize aggressive interactions and improve the acceptance of piglets. Observing sow behaviour prior to fostering can help identify suitable candidates. Furthermore, since foster sows terminate nursing bouts more frequently, adjusting the environment to minimize stressors, such as reducing noise levels, may provide a quite environment for suckling. The wandering squealing syndrome exhibited by foster piglets indicates their distress and potential difficulty in adapting to their new surroundings. Implementing gradual introductions (co-mingling) provides a form of socialization that can reduce stress and anxiety. Additionally, since resident piglets frequently attack fostered piglets, managing group dynamics by isolating foster piglets and integrating them slowly could reduce aggression. Implement structured fostering practices, for example, not to re-foster a piglet once it has already been fostered. This limits the frequency of introducing new piglets to a sow to allow her to focus on a stable group. Lastly, ensuring foster sows receive proper nutrition to support milk production can help meet the needs of all piglets.

6 Interventions likely to reduce the negative behaviours

(i) Selection of the N/F sow and allocating piglets

Suggestions have been made to select foster sows that are still young in lactation [5, 78]. The success of nurse or foster sow strategies depends on the stage of sow lactation. During lactation, the nutritional composition of milk changes from colostrum to milk [79]. Sows selected in later lactation days may have lower milk yields [80] and lower immunoglobulin concentrations

[81]. This makes it more likely that the sow will not nurse, and the piglets will get hungrier, increasing their chances of fighting for limited resources. Foster sows should be given equal or less number of foster piglets compared to the previous they were nursing [47]. It is believed that each previous piglet was suckling from a functional teat. This enables fostered piglets to nurse from available functional teats continuously. Furthermore, moving the foster sow into the crate first, letting it become used to the environment, and then giving it foster piglets (author observation).

(ii) Litter uniformity

The uniformity of the adopted litter should be considered. Composing piglets of the same age bracket, small, medium, or large/heavy. Grouping piglets of similar size and age can minimize competition for nursing, ensuring that each piglet has adequate access to milk [82-83]. When piglets are uniform in size, the nursing process becomes more efficient, ensuring social stability and reducing competition.

(iii) Olfactory masking

Foster/Nurse piglets smell differently from the sows own biological piglets; hence, there is a need to mask their smell to aid faster acceptance. Various scent masks are utilized in pig farms to minimize olfactory differences, such as using baby pig powder (author observation), or grouping sows own piglets and foreign piglets prior to adoption. Baby pig powder is used to mask the smell of the environment by dusting piglets with it immediately after they are introduced to the N/F sow. With this type of masking, discrimination can lessen because the sow is unable to identify the new piglets by their original scent. Malentiska et al. [38] reported evidence of successful use of scent masking when sows significantly differentiated familiar own piglets from unfamiliar own piglets based on the individual odour of the piglets. Sows failed to react differently to odour-masked piglets [84], indicating that masking provided an opportunity for all piglets to be

accepted. In a study by Aro et al. [85], when piglets were rubbed with an odoriferous chemical and grafted into the litter, the dam provided a higher percentage of acceptance to the piglets when masked.

(iv) Socialization Strategies

Gradual socialization techniques can also be effective. For instance, allowing foster piglets to interact with the sow or resident piglets in a controlled setting before full integration. This may involve short, supervised interactions that build familiarity. The benefits of this socialization during lactation go a long way to reducing the level of aggression at weaning and improving social skills [15-16]. Furthermore, Pre-weaning socialization has a significant impact on improving pig welfare [86] and positively affects pig behaviour pre- and post-weaning [87-88].

7 Conclusions

The behavioural manifestations of nurse/foster sows and their piglets during lactation were compared in this review. Nurse and foster sows showed discriminatory behaviour, directed hostility, and aggression toward nurse and foster piglets. Moreover, nurse and foster sows have a longer delay to milk let-down and terminate nursing more frequently. Increased vocalisations and wandering behaviours, including actions such as escape attempts, are signs of nurse and foster piglet's immediate behavioural experience. More post-teat massage phenomena, or "begging" for more milk, is observed in nurse/foster piglets. The review has contributed to understanding pig lactation behaviour and pointed out certain gaps that may require further investigation. Additionally, possible measures that could ameliorate undesired behaviours have been suggested.

8 Future research

Pig behaviour science enables stockpersons to comprehend and interpret the demands of pigs expressed through their behaviour. It is important to highlight from this review that nurse and foster sows show aggressive behaviour directed towards adoptive piglets and even reject them. This behaviour not only puts the young piglets' lives in danger physically but also jeopardizes their ability to get the nourishment they need. Research on efficient methods to ensure that nurse and foster sows accept nursing piglets more quickly may provide useful farm solutions that might lessen unwanted behaviours, such as aggression and potential rejection. Nurse sows have an added burden of suckling beyond their conventional lactation period, putting strain on them to produce milk regardless of the piglet's age. Using nutritional strategies aimed at generating diets that can boost the milk supply of nurse sows could perhaps reduce the common fights among piglets when they 'run out of milk.'

Furthermore, it has been observed that "post teat" massages are associated with "begging" for more milk.

Post-teat massage may be viewed as stereotypical behaviour. Research in this area could provide information on whether the lifetime stereotypic behaviours displayed by some sows may be connected to their early life post-teat massage. These results can be applied to enhance nutrition and environmental conditions to reduce the expression of behaviour.

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References

1. A. Balzani, H.J Cordell, S.S Edwards, Relationship of sow udder morphology with piglet suckling behaviour and teat access. *Theriogenology*. **86**, (2016).
2. L. Pajzlar, J. Skok, Cross-fostering into smaller or older litter makes piglets integration difficult: Suckling stability-based rationale. *Appl. Anim. Behav. Sci.* **220**, 104856.(2019)
3. Australian Pork Limited APL project 2016/2237, Cross fostering guidelines for Australian farrowing houses, 2017.
4. S. Robert, G.P Martineau, Effects of repeated cross-fosterings on preweaning behavior and growth performance of piglets and on maternal behavior of sows. *J. Anim. Sci.* **79**, (2001).<https://doi.org/10.2527/2001.79188x>
5. E. M Baxter, K.M.D Rutherford, R.B D'eath, G. Arnott, S.P Turner, P. Sandøe, A.B Lawrence, The welfare implications of large litter size in the domestic pig II: management factors. *Anim. Welf.* **22**, (2013).
6. C. Kobek-Kjeldager, V.A Moustsen, P.K Theil, L .J Pedersen, Managing large litters: Selected measures of performance in 10 intermediate nurse sows and welfare of foster piglets. *Appl. Anim. Behav. Sci.* **233**, 105149 (2020).
<https://doi.org/10.1016/j.applanim.2020.105149>
7. F. P Bortolozzo, G.P Zanin, R. Ulguim, A. P.G Mellagi, Managing Reproduction in Hyperprolific Sow Herds. *Animals*. **13**,

- 13111842 (2023).
<https://doi.org/10.3390/ani13111842>
8. K. Portele, K. Scheck, S. Siegmann, R. Feitsch, K. Maschat, J.L Rault, I. Camerlink, Sow-piglet nose contacts in free-farrowing pens. *Animals*. **9**,(2019) <https://doi.org/10.3390/ani9080513>
 9. C. Clouard, R. Resmond, A. Prunier, C. Tallet, E. Merlot, Exploration of early social behaviors and social styles in relation to individual characteristics in suckling piglets. *Science Reports -UK*, **12**, (2022) <https://doi.org/10.1038/s41598-022-06354-w>
 10. L. Loftus, G. Bell, E. Padmore, S. Atkinson, A. Henworth, M. Hoyle, The effect of two different farrowing systems on sow behaviour, and piglet behaviour, mortality and growth. *Appl. Anim. Behav. Sci.* **232**, 105102 (2020). <https://doi.org/10.1016/j.applanim.2020.105102>
 11. H. B Rooney, O. Schmitt, A. Courty, P.G Lawlor, K. O'Driscoll, Like mother like child: do fearful sows have fearful piglets?. *Animals*. **11**, (2021).
 12. M. Ocepek, I.L Andersen, Sow communication with piglets while being active is a good predictor of maternal skills, piglet survival and litter quality in three different breeds of domestic pigs (*Sus scrofa domestica*). *PLoS One*, **13**, (2018) <https://doi.org/10.1371/journal.pone.0206128>.
 13. L. Blavi, D. Solà-Oriol, P. Llonch, S. López-Vergé, S.M Martín-Orúe, J.F Pérez, Management and feeding strategies in early life to increase piglet performance and welfare around weaning: A review. *Animals*. **11**, (2021).
 14. A.K Johnson, J.L Rault, J.N Marchant, E.M Baxter, K. O'Driscoll, Improving young pig welfare on-farm: The Five Domains Model. *J. Anim. Sci.* **100**, (2022).
 15. I. Camerlink, M. Farish, R.B D'eath, G. Arnott, S.P Turner, Long term benefits on social behaviour after early life socialization of piglets. *Animals*, **8**, 8110192 (2018) <https://doi.org/10.3390/ani8110192>
 16. L.C Salazar, H.L Ko, C. Yang, L. Llonch, X. Manteca, I. Camerlink, P. Llonch, Early socialisation as a strategy to increase piglets' social skills in intensive farming conditions. *Appl. Anim. Behav. Sci.* **206**, (2018) <https://doi.org/10.1016/j.applanim.2018.05.033>
 17. J.G Alexopoulos, D.S Lines, S Hallett, K.J Plush, A review of success factors for piglet fostering in lactation. *Animals*. **8**, (2018).
 18. K.M.D Rutherford, E.M Baxter, R.B D'eath, S.P Turner, G. Arnott, R. Roehe, A.B Lawrence, B. The welfare implications of large litter size in the domestic pig I: biological factors. *Anim. Welf.* **22**, (2013) <https://doi.org/10.7120/09627286.22.2.199>
 19. E. M Baxter, O. Schmitt, L.J Pedersen, Managing the litter from hyperprolific sows. In *The suckling and weaned piglet*, Wageningen Academic Publishers. (2020): https://doi.org/10.3920/978-90-8686-894-0_3
 20. B. Puppe, A. Tuchscherer, The development of suckling frequency in pigs from birth to weaning of their piglets: a sociobiological approach. *J. Anim. Sci.* **72**, (2000) <https://doi.org/10.1017/S1357729800055119>
 21. S. Kasanen, B. Algers, (2002). A note on the effects of additional sow gruntings on suckling behaviour in piglets. *Appl. Anim. Behav. Sci.* **75**, (2002).
 22. R. Y Lohmeier, C.G.E Gimberg-Henrici, O. Burfeind, J. Krieter, Suckling behaviour and health parameters of sows and piglets in free-farrowing pens. *Appl. Anim. Behav. Sci.* **211**, (2019).
 23. E.M Rosvold, R.C Newberry, I.L Andersen, Early mother-young interactions in domestic sows – Nest-building material increases maternal investment. *Appl. Anim Behav. Sci.* **219**, 104837 (2019) <https://doi.org/10.1016/j.applanim.2019.104837>
 24. M.L Pedersen, V.A Moustsen, M.B.F Nielsen, A.R Kristensen, Improved udder access prolongs duration of milk letdown and increases piglet weight gain. *Livest. Sci.* **140**, (2011) <https://doi.org/10.1016/j.livsci.2011.04.001>
 25. R.I King, S.M Matheson, E.M Baxter, S. A Edwards, Sow behaviour and piglet weight gain after late cross-fostering in farrowing crates and pen, *Animal*. **14**, (2020) <https://doi.org/10.1017/S1751731120000580>
 26. O. Schmitt, E.M Baxter, L.A Boyle, K. O'Driscoll, Nurse sow strategies in the domestic pig: I. Consequences for selected measures of sow welfare. *Animal*. **13**, (2019a) <https://doi.org/10.1017/S175173111800160X>
 27. J. Skok, D. Skorjanc, Group suckling cohesion as a prelude to the formation of teat order in piglets. *Appl. Anim. Behav. Sci.* **154**, (2014).
 28. R. I Horrell, Immediate behavioural consequences of fostering 1-week-old piglets. *J. Agric. Sci.* **99**, (1982) <https://doi.org/10.1017/S0021859600030100>
 29. E.T Gieling, R.E Nordquist, F.J van der Staay, Assessing learning and memory in pigs. *Anim. Cog.* **14**, (2011) <https://doi.org/10.1007/s10071-010-0364-3>
 30. G. Heim, A.P.G Mellagi, T. Bierhals, L.P de Souza, H.C.C de Fries, P. Piuco, E. Seidel, M.L Bernardi, I. Wentz, F.P Bortolozzo, (2012) Effects of cross-fostering within 24h after birth on pre-weaning behaviour, growth performance and survival rate of biological and adopted piglets. *Lives. Sci.* **150**, (2021) <https://doi.org/10.1016/j.livsci.2012.08.011>
 31. L. Lidfors, C. Berg, B. Algers, Integration of natural behavior in housing systems. *AMBIO: A J. Hum Environ.* **34**, (2005).

32. C. J Mayerl, R.Z German, Evolution, diversification and function of the maternal–infant dyad in mammalian feeding. *Philos. Trans. R. Soc. B.* **378**, (2023).
33. H. Telkanranta, S.A Edwards, Lifetime consequences of the early physical and social environment of piglets. In *Advances in Pig Welfare*. (2018) <https://doi.org/10.1016/B978-0-08-101012-9.00013-7>
34. K.L Chidgey, P.C Morel, K.J Stafford, I.W Barugh, The performance and behaviour of gilts and their piglets is influenced by whether they were born and reared in farrowing crates or farrowing pens. *Livest. Sci.* **193**, (2016).
35. G. Miguel-Pacheco, Y.M Seddon, Developmental influences on pig behaviour. In *Understanding the behaviour and improving the welfare of pig*. Burleigh Dodds Science Publishing. (2021)
36. O. Schmitt, E.M Baxter, L.A Boyle, K. O’driscoll, Nurse sow strategies in the domestic pig: II. Consequences for piglet growth, suckling behaviour and sow nursing behaviour. *Animal.* **13**, (2019b) <https://doi.org/10.1017/S1751731118001702>
37. A. E Valros, M. Rundgren, M. Špinka, H. Saloniemi, L. Rydhmer, B. Algers, Nursing behaviour of sows during 5 weeks lactation and effects on piglet growth. *Appl. Anim. Behav. Sci.* **76**, (2002) [https://doi.org/10.1016/S0168-1591\(02\)00006-0](https://doi.org/10.1016/S0168-1591(02)00006-0)
38. J. Maletinska, M. Spinka, J. Vichova, I. Stehulova, Individual recognition of piglets by sows in the early post-partum period. *Behav.* **139**, (2002).
39. S.A Ward, R.N Kirkwood, K.J Plush, Are larger litters a concern for piglet survival or an effectively manageable trait?. *Animals.* **10**, (2020).
40. X. Zhang, M.Wang, T. He, S. Long, Y. Guo, Z. Chen, Effect of different cross-fostering strategies on growth performance, stress status and immunoglobulin of piglets. *Animals.* **11**, (2021).
41. M. Spinka, G. Illmann, B. Algers, Z. Stetkova, The role of nursing frequency in milk production in domestic pigs. *J. Anim. Sci.* **75**, (1997).
42. L.J Pedersen, M. Studnitz, K.H Jensen, A.M Giersing, Suckling behaviour of piglets in relation to accessibility to the sow and the presence of foreign litters. *Appl. Anim. Behav. Sci.* **58**, (1998) [https://doi.org/10.1016/S0168-1591\(97\)00149-4](https://doi.org/10.1016/S0168-1591(97)00149-4)
43. E. M Baxter, S.A Hall, M. Farish, J. Donbavand, M. Brims, M. Jack, A.B Lawrence, I. Camerlink, Piglets’ behaviour and performance in relation to sow characteristics. *Anima.* **17**, 100699 (2023) <https://doi.org/10.1016/j.animal.2022.100699>
44. S. Torrey, T.M Widowski, Relationship between growth and non-nutritive massage in suckling pigs. *Appl. Anim. Behav. Sci.* **107**, (2007).
45. M. Spinka, B. Algers, Functional view on udder massage after milk let-down in pigs. *Appl. Anim. Behav. Sci.* **43**, (1995).
46. P. Jensen, M. Gustafsson, H. Augustsson, Teat massage after milk ingestion in domestic piglets: An example of honest begging?, *Anim. Behav.* **55**, (1998) <https://doi.org/10.1006/anbe.1997.0651>
47. J. T Sorensen, T. Rousing, A.B Kudahl, H. J Hansted, L.J Pedersen, Do nurse sows and foster litters have impaired animal welfare? Results from a cross-sectional study in sow herds. *Animal.* **10**, (2016).
48. G. P Zanin, L. Santos, D.M.S Tomm, D.F Silveira, F.P Bortolozzo, R.R Ulguim, A.P.G Mellagi, Sow and litter performance after cross-fostering one surplus piglet and comingling the litters at early lactation. *Animal.* **10**, 101247 (2024).
49. I .Dostaiikova, M. Spinka, P. Kindlmann, Begging for milk: evolution of teat massaging in suckling pigs. *J. Theoret. Biol.* **215**, (2002).
50. K. Olczak, W. Penar, J. Nowicki, A. Magiera, C. Klocek, The Role of Sound in Livestock Farming— Selected Aspects. *Animals.* **13**, 13142307 (2023) <https://doi.org/10.3390/ani13142307>
51. D. Reese, B. Straw, The case against evening-up litters until weaning, *Nebraska Swine Reports.* **212**, (2006) https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1227%26context=coopext_swine
52. P.C Schon, B. Puppe, G. Manteuffel, Automated recording of stress vocalisations as a tool to document impaired welfare in pigs. *Anim. Welf.* **13**, (2004) <https://doi.org/10.1017/S096272860002683X>
53. A. Drake, D. Fraser, D.M Weary, Parent–offspring resource allocation in domestic pigs. *Behav. Ecol. Sociobiol.* **62**, (2008).
54. J. Skok, Suckling strategies in terrestrial ungulates (Artiodactyla, Perissodactyla) and the factors influencing them: The offspring perspective. *CABI Reviews.* (2022).
55. E. Collarini, L. Capponcelli, A. Pierdomenico, I. Norscia, G. Cordon, Sows’ Responses to Piglets in Distress: An Experimental Investigation in a Natural Setting. *Animals.* **13**, (2023).
56. D. M Weary, G.L Lawson, B.K Thompson, Sows Show Stronger Responses to Isolation Calls of Piglets Associated with Greater Levels of Piglet Need. *Anim. Behav.* **52**, (1996).
57. G. Illmann, J. Zachařová, J. Maletinská, I. Stěhulová, M. Špinka, M. Nursing Behaviour and Nursing Vocalisations in Domestic Sows: Repeatability and Relationship with Maternal Investment. *Behav.* **139**, (2002)
58. M. C Appleby, D.M Weary, A.A Taylor, G. Illmann, Vocal communication in pigs: Who

- are nursing piglets screaming at?. *Ethol.* **105**,(1999) <https://doi.org/10.1046/j.1439-0310.1999.00459.x>
59. J. K Blackshaw, A.M Hagelsø, Getting-up and lying-down behaviours of loose-housed sows and social contacts between sows and piglets during day 1 and day 8 after parturition. *Appl. Anim. Behav. Sci.* **25**,(1990)
60. H. L Ko, D. Temple, J. Hales, X. Manteca, P. Llonch, Welfare and performance of sows and piglets in farrowing pens with temporary crating system on a Spanish commercial farm. *Appl. Anim. Behav. Sci.* **246**, 105527(2022).
61. K.L Chidgey, P.C Morel, K.J Stafford, I.W Barugh, Sow and piglet behavioral associations in farrowing pens with temporary crating and in farrowing crates. *J. Vet. Behav.* **20**, (2017).
62. B. Algers, K. Uvnas-Moberg, Maternal behavior in pigs. *Horm. Behav.* **52**,(2007) <https://doi.org/10.1016/j.yhbeh.2007.03.022>
63. L.P Souza, H.C.C Fries, G. Heim, J.E Faccin, L.F Hernig, B.T Marimon, M.L Bernardi, F. P Bortolozzo, I. Wentz, Behaviour and growth performance of low-birth-weight piglets cross-fostered in multiparous sows with piglets of higher birth weights. *Arquivo Brasil. Med. Vet. Zootec.* **66**, (2014). <https://doi.org/10.1590/1678-41626379>
64. E. O Price, G.D Hutson, M.I Price, R. Borgwardt, Fostering in swine as affected by age of offspring. *J. Anim. Sci.* **72**,(1994) <https://doi.org/10.2527/1994.7271697x>
65. M. E Lucas, L.M Hemsworth, P.H Hemsworth, Early life piglet experiences and impacts on immediate and longer-term adaptability. *Animal.* 100889(2023).
66. N. E O'Connell, V.E Beattie, I.A Sneddon, K. Breuer, J.T Mercer, K.A Rance, M.E.M Sutcliffe, S.A Edwards, Influence of individual predisposition, maternal experience and lactation environment on the responses of pigs to weaning at two different ages. *Appl. Anim. Behav. Sci.* **90**,(2005) <https://doi.org/10.1016/j.applanim.2004.08.012>
67. I. Camerlink, S.P Turner, W.W Ursinus, I. Reimert, J.E Bolhuis, Aggression and affiliation during social conflict in pigs. *PLoS ONE.* **9**,(2014) <https://doi.org/10.1371/journal.pone.0113502>
68. J. M Clarkson, E. M Baxter, J. E Martin, Who plays with whom: farrowing environment influences isolation of foster piglets in play. *Front. Anim. Sci.* **2**, 724080(2021).
69. M.D Gomboc, J. Skok, D. Skorjanc, M.P Povse, Suckling Behaviour of Piglets Affected by Body Weight and Sex. *Agric. Scient.* **20**,(2023) <https://doi.org/10.18690/agricsci.20.1.4>
70. A. N. W Olsen, L. Dybkjaer, K.S Vestergaard, Cross-suckling and associated behaviour in piglets and sows. *Appl. Anim. Behav. Sci.* **61**,(1998) [https://doi.org/10.1016/S0168-1591\(98\)00182-8](https://doi.org/10.1016/S0168-1591(98)00182-8)
71. J. Skok, D. Skorjanc, Formation of teat order and estimation of piglets' distribution along the mammary complex using mid-domain effect (MDE) model. *Appl. Anim. Behav. Sci.* **144**,(2013) <https://doi.org/10.1016/j.applanim.2012.11.014>
72. T. Kutzer, B. Bünger, J.B Kjaer, L. Schrader, Effects of early contact between non-littermate piglets and of the complexity of farrowing conditions on social behaviour and weight gain. *Appl. Anim. Behav. Sci.* **121**, (2009).
73. S. Giroux, S. Robert, G.P Martineau, The effects of cross-fostering on growth rate and post-weaning behavior of segregated early-weaned piglets. *Can. J. Anim. Sci.* **80**, (2000).
74. W. Ji, Y. Bi, Z. Cheng, R. Liu, X. Zhang, Y. Shu, H. Liu, Impact of early socialization environment on social behavior, physiology and growth performance of weaned piglets. *Appl. Anim. Behav. Sci.* **238**, 105314(2021).
75. C. Van Kerschaver, M. Vandaele, J. Degroote, K. Van Tichelen, D. Fremaut, C. Van Ginneken, J. Michiels, Effect of starting time of co-mingling non-littermates during lactation on performance and skin lesions of sows and piglets. *Livest. Sci.* **250**, 104563(2021).
76. C. A Parratt, K.J Chapman, C. Turner, P.H Jones, M.T Mendl, B.G Miller, The fighting behaviour of piglets mixed before and after weaning in the presence or absence of a sow. *Appl. Anim. Behav. Sci.* **101**, (2006).
77. M.G.H Deen, G. Bilkei, Cross fostering of low-birthweight piglets. *Lives. Prod. Sci.* **90**, (2004).
78. T.S Bruun, C. Amdi, J. Vinther J, M. Schop, A.B Strathe, C.F Hansen, Reproductive performance of "nurse sows" in Danish piggeries. *Theriogenology.* **86**, (2016).
79. M. V Curtasu, P.K Theil, M.S Hedemann, Metabolomic profiles of colostrum and milk from lactating sows. *J. Anim. Sci.* **94**, (2016).
80. F. Klobasa, E. Werhahn, J.E Butler, Composition of sow milk during lactation. *J. Anim. Sci.* **64**, (1987) <https://doi.org/10.2527/jas1987.6451458x>
81. W. L Hurley, Composition of sow colostrum and milk. In C. Farmer (Ed.), *The gestating and lactating sow.* Wageningen Academic Publishers. (2015). <https://doi.org/10.3920/978-90-8686-803-2-8>
82. K.D Vande Pol, R.O Bautista, H. Harper, C. M Shull, C.B Brown, M. Ellis, Effect of within-litter birth weight variation after cross-fostering on piglet preweaning growth and mortality. *Translat. Anim. Sci.* **5**,(2021b) <https://doi.org/10.1093/tas/txab039>
83. F. Thorup, M. B. F Nielsen, The growth decreases when small piglets stay with their own mother at litter equalization. Danish: Tilvæksten falder når de små pattegrise bliver

- hos egen mor ved kuldudjævning. SEGES Svineproduktion.(2017)
84. I. Horrell, J. Hodgson, The bases of sow-piglet identification. 1. The identification by sows of their own piglets and the presence of intruders. *Appl. Anim Behav. Sci.* **33**, (1992).
 85. Aro, S. O Aro, O. Olowofeso, J.O Agbede, The influence of mutual maternal and neonatal recognition on the foster mothering techniques in pigs. *Nigerian J. Anim.Prod.* **35**, (2008)
 86. H. L. Ko, Q. Chong, D. Escribano, I. Camerlink, X. Manteca, P. Llonch, Pre-weaning socialization and environmental enrichment affect life-long response to regrouping in commercially-reared pigs. *Appl. Anim. Behav. Sci.* **229**, (2020).
 87. T. Morgan, J. Pluske, D. Miller, T. Collins, A.L Barnes, F. Wemelsfelder, P. A Fleming, (2014). Socialising piglets in lactation positively affects their post-weaning behaviour. *Appl. Anim. Behav. Sci.* **158**, (2014)
 88. J. E Weller, I. Camerlink, S.P Turner, M. Farish, G. Arnott, Socialisation and its effect on play behaviour and aggression in the domestic pig (*Sus scrofa*). *Scientific Reports.* **9**, (2019).