https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

10. Housing, management and environment during farrowing and early lactation

O.A.T. Peltoniemi and C. Oliviero
University of Helsinki, Dept. Production Animal Medicine, Paroninkuja 20, 04920 Saarentaus, Finland; olli.peltoniemi@helsinki.fi, claudio.oliviero@helsinki.fi

Abstract

The determination of successful farrowings includes components of maternal behaviour, duration of farrowing, piglet mortality and colostrum intake. Duration of farrowing can be used as a simple measure of whether or not a farrowing can be considered successful. We suggest a time limit of 300 minutes for a successful farrowing. In addition to its well-known benefits, human intervention by means of exogenous hormones during parturition comprises risks which should be considered. Induction of farrowing by prostaglandin administration may lead to immature piglets being born with congenital complications. Over use/routine use of oxytocin may reduce placental blood flow and thereby expose fetuses remaining in the uterus to hypoxia. Pain management of the sow at farrowing is an issue of high importance for a successful beginning of lactation and whenever abnormal nursing behaviour is observed, pain should be considered as a potential cause. Feeding is considered the major factor for reproductive management of the hyperprolific sow around farrowing. New insights such as adding more fiber to sow diets during pregnancy, and especially during the period prior to farrowing, may prevent constipation, increase water intake of the sow around parturition and increase milk intake and performance of piglets. Use of modern technology in supervision of farrowings may decrease losses related to large litters. In breeding programs, new components of maternal characteristics, such as maternal behaviour, ease of parturition, colostrum production, and piglet quality parameters, may be utilized to further improve success rate of reproductive management during farrowing and early lactation.

Keywords: sow, feeding, pain, hormones, constipation

10.1 Introduction

Farrowing is a key event in the production life of a sow and it has a substantial economic impact on piglet production. Years of breeding selection in pig production have achieved excellent results in increasing the total number of piglets born per litter. However, there is evidence of a negative association between litter size and individual piglet birth weight (Kerr and Cameron, 1995; Roehe, 1999; Sorensen *et al.*, 2000), and of an increase in the proportion of piglets born dead along with increasing litter size (Sorensen *et al.*, 2000). Feeding strategies have also aimed at increasing sow milk yield in order to better support the growth of all the piglets during the pre-weaning phase (Einarsson and Rojkittikhun, 1993). The productive cycle of sows has become faster, with a reduced duration of

DOI 10.3920/978-90-8686-803-2_10, © Wageningen Academic Publishers 2015

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

lactation and a shorter weaning-to-oestrus interval, in order to maximise the number of piglets each sow produces annually. Swine breeding farms have become much larger in recent years, often with a functional distribution of space that limits the room available for each sow. All these changes have contributed to increasing environmental pressure on the sow at farrowing.

10.2 Physiology of farrowing

The physiology of farrowing is very complex. Indeed, several hormones act and interact to regulate the farrowing process. In the latest stages of pregnancy, hormones such as progesterone, LH, estrogens, cortisol, prolactin, relaxin, and prostaglandins become the main actors that regulate all the physical events leading to parturition (Figure 10.1). All these hormones, regulated by various internal clocks and signalling systems, interact and influence each other in a very refined manner (Anderson, 2000).

Behavioural expression is also very important for the farrowing process. Sows express an innate hormone-driven nest-building behaviour which signals the beginning of parturition (Algers and Uvnäs-Moberg, 2007). However, the environment can also have an important, though indirect, influence on the pattern of these hormones. For example, a restricting environment can influence nest-building behaviour, especially in modern swine production systems, where the sow is pressured by several external factors (Damm *et al.*, 2003). This refined, delicate hormonal process clearly requires very well-defined premises in order to proceed properly. In addition to housing, nutrition and disease may

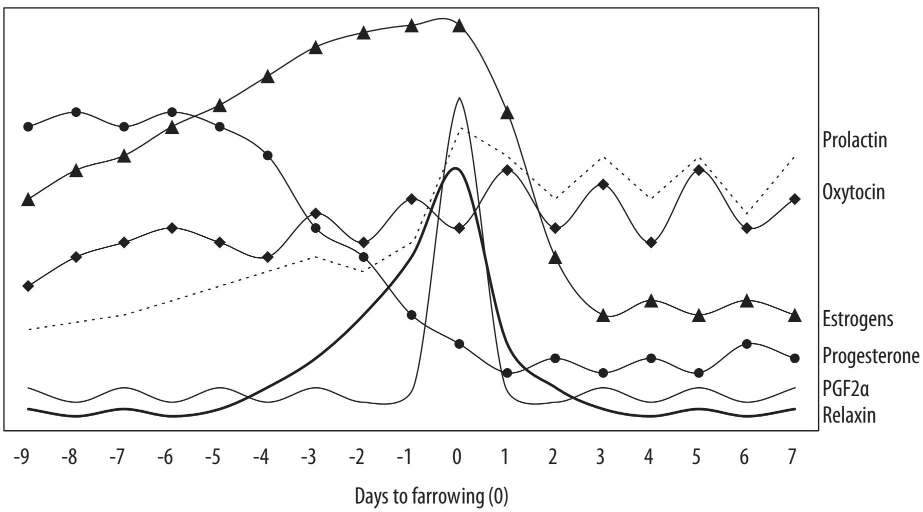


Figure 10.1. A schematic description of the concentrations of reproductive hormones during pregnancy in the sow (modified from Anderson, 2000). Hormones concentrations undergo major changes only a few days before farrowing.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

also affect, either directly or indirectly, the release or activity of hormones that interfere with the farrowing process.

During early pregnancy, after implantation of the embryos and developmental activity of the corpora lutea, higher and constant concentrations of progesterone dominate the hormonal pattern (Meulen *et al.*, 1988). This preserves the progress of pregnancy and, for almost two thirds of pregnancy, the circulating concentrations of progesterone remain high. At approximately 24 to 48 h before the beginning of parturition, the quick drop in progesterone concentrations initiates a cascade effect on many other hormones, which had quite stable concentrations throughout pregnancy. The concentration of prostaglandins peaks, that of oxytocin increases and begins to exhibit high pulsating activity (Gilbert *et al.*, 1994), prolactin concentration gradually increases, and that of estrogens, after peaking quickly, gradually drops to basal levels (Anderson, 2000; Ellendorff *et al.*, 1979; Kindahl *et al.*, 1982) (Figure 10.1). The period of farrowing is therefore linked to numerous large hormonal changes taking place over a very limited time. Also, cortisol peaks at farrowing, rising to 2-3 times the basal concentrations and then levelling down within 24-36 h (Oliviero *et al.,* 2008a; Osterlundh *et al.*, 1998).

10.3 Behaviour and activity

Before and during farrowing, the intense hormonal activity described above is responsible not only for inducing the process of parturition, but also for triggering visible behavioural changes. Activities such as rooting, pawing, turning and walking increase considerably 24 h prior to farrowing (Hartsock and Barczewski, 1997) and characterize the nest-building behaviour. One of the triggering factors of nest-building behaviour was found to be a rise in prolactin (Castrén *et al.*, 1994), induced by a decrease in progesterone and an increase in prostaglandins (Algers and Uvnäs-Moberg, 2007). The external influence of the environment is also important for the expression of nest-building behaviour. Indeed, the availability of proper nest-building material seems to speed up this process (Damn *et al.*, 2000). Modern housing systems have promoted the confinement of sows in crates during farrowing, whereby the sow has very limited movement and bedding or any other nest-building substrate is often absent or very limited. In these particular conditions, the nest-building behaviour triggered by endogenous hormonal activity cannot be properly expressed. In the absence of a nest-building substrate, confined sows express prolonged and unsuccessful nest-building behaviour (Damn *et al.*, 2003). The lack of opportunity to express appropriate nest-building behaviour can lead to increases in circulating cortisol and adrenocorticotropic hormone (Jarvis *et al.*, 1997), which indicate a stressful condition. Gustafsson *et al.* (1999) found that domestic sows were able to build nests identical to those of wild boars, even after several previous farrowing experiences in confined crates without bedding. This innate behaviour is therefore a clear indicator of impending farrowing and is present regardless of housing or availability of bedding material.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

10.4 Successful farrowing

A prerequisite for successful farrowing is that the sow has the tools to properly express its nest-building behaviour, such as the availability of nest-building material and the ability to move freely. In addition, it is important that sows receive a diet that reduces constipation and the risk for obesity. Furthermore, farrowing can be considered successful if the total duration of parturition is shorter than 5 h, and if more than 90% of the piglets are born alive and survive the following 72 h. The final criteria of a successful farrowing include that piglets receive colostrum and that the sow and piglets experience no complications. Typical complications to be avoided include intra-partum hypoxia of the fetus and contamination and subsequent inflammation of the birth canal in the case of the sow.

10.5 Farrowing environment

The modern swine industry uses four basic types of farrowing accommodation: the farrowing crate, the sow pen, indoor group-housing and outdoor extensive housing. In Europe and North America, the most widely used farrowing accommodations are the sow pen and the farrowing crate, the latter being largely predominant (Hartsock and Barczewski, 1997; Jensen *et al.*, 1997; Kemp and Soede, 2012).

10.5.1 Housing: the crate and the pen

Farrowing crates usually consist of a system of bars which confine the sow to a limited space where she can lie down or stand, but cannot turn or move around. Farrowing crates are often placed on concrete, slatted floors or a combination of the two. The use of roughage or bedding for farrowing sows is regulated by European legislation describing only the minimum standards required (91/630/EEC). The situation can therefore vary considerably between countries, but roughage is usually very limited or completely absent. In this particular environment, the sow has fewer opportunities to express proper nest-building behaviour. In the absence of a suitable substrate, the sow directs her activities towards the floor and the bars of the crate (Lawrence *et al.*, 1994). Crated sows stand up more often before the onset of parturition than do sows in pens (Hansen and Curtis, 1980). The farrowing crate was designed to minimise piglet losses due to crushing (Edwards and Fraser, 1997). Some studies have indeed reported that keeping sows in crates reduces crushing compared with keeping them in pens (Cronin *et al.*, 1996), however, several other studies found no differences (Aumaitre and Le Dividich, 1984; Fraser, 1990; Phillips and Fraser, 1993). A recent field study in Denmark suggests a further need for research in order to provide producers with tools to cope with the challenges of loose housing during lactation (Hales *et al.*, 2014). Farrowing pens can vary in size and structure, with the larger ones permitting the sow to move freely and to turn around. During the 24 h before parturition, sows in pens turn and walk more frequently than do crated sows, whose activities are limited (Hartsock and Barczewski, 1997). Providing more space, even without straw, promotes the expression of maternal behaviour during farrowing (Jarvis *et al.*, 2004). Vestergaard and Hansen (1984) found that sows under confinement before or during farrowing had prolonged farrowings. This

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

increased farrowing time was either the direct result of less optimal conditions for nest-building, or the indirect result of subsequent stress. Because pens allow the sow to better express nest-building behaviour, at least in part, they are beneficial to the health and welfare of both the sow and the piglets (Algers, 1994).

10.5.2 Effects of housing on hormonal variables associated with farrowing

There is evidence that sows housed in crates show greater salivary cortisol concentrations than sows in pens between 2 and 5 days post-farrowing (Oliviero *et al.*, 2008a). In the penned group, during that period, cortisol concentrations returned to their pre-farrowing levels instead of remaining higher as in crated group (Figure 10.2). This greater level of salivary cortisol in crated sows could be linked to the prolonged duration of farrowing. As previously mentioned, the lack of an environment in which the sow can fully express nest-building behaviour (Jarvis *et al.*, 2002) contributed to raise the stress level beyond a threshold above which other physiological mechanisms may have been altered. Lower concentrations of oxytocin found in crated sows may explain such an alteration (Oliviero *et al.*, 2008a) because insufficient concentrations of oxytocin at parturition are thought to be an important cause of prolonged farrowing (Castrén *et al.*, 1993).

The average post-expulsion oxytocin pulse concentration (measured within 6 min after expulsion of the piglet) for sows housed in crate was shown to tend to be lower than that for sows housed in pens (Oliviero *et al.*, 2008a). The duration of farrowing was strongly associated with these oxytocin concentrations. In addition, without taking into consideration the different housing, farrowings longer than 5 h were strongly associated with lower oxytocin concentrations.

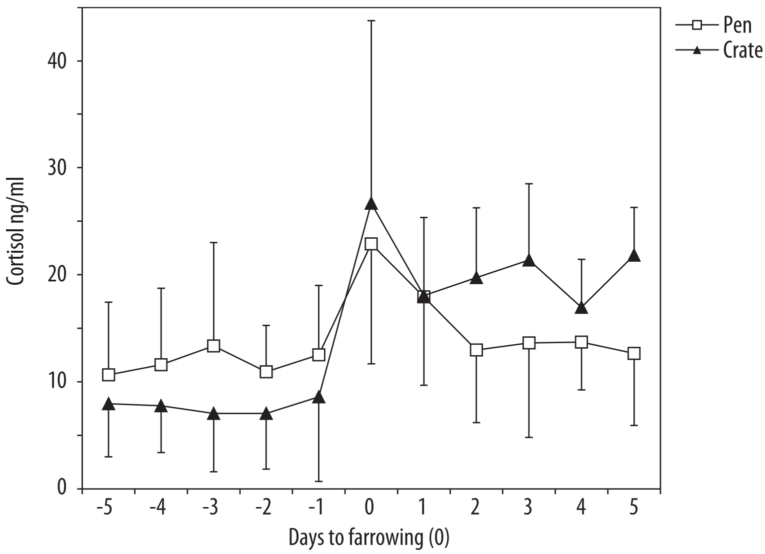


Figure 10.2. Average salivary cortisol concentrations for sows housed in pens and in crates. Results are means ± standard deviation (Oliviero et al.*, 2008a).*

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

10.5.3 Housing and its effect on duration of farrowing and piglet mortality

There appears to be a clear connection between housing and piglet mortality as they both relate to farrowing duration (Table 10.1). Many studies found that housing in crates prolongs farrowing by 90 min on average, with crated sows having farrowings that last over 300 min. Similarly, a farrowing duration of over 300 min was associated with a higher stillborn rate compared with farrowings lasting less than 200 min (Gu *et al.*, 2011; Oliviero *et al.*, 2008a, 2010).

The association between longer duration of farrowing and the greater incidence of stillborn piglets is even stronger without considering the housing. Sows with a duration of farrowing longer than 300 min had 1.4±1.5 (mean ± SD) stillborn piglets, whereas sows with a duration of farrowing shorter than 300 min had 0.5±0.9 stillborn piglets (Oliviero *et al.*, 2008a). The longer duration of farrowing for sows housed in farrowing crates instead of pens may be connected to the crate itself and to the absence of an adequate substrate for nest-building. Both these factors may interfere with the natural expression of the sow's nest-building behaviour, thereby increasing the sow's level of stress at farrowing (Lawrence *et al.*, 1994; Thodberg *et al.*, 1999). As previously discussed, the high concentrations of circulating cortisol present during farrowing demonstrate that parturition in itself triggers a stress-mediated response in the sow. This interaction between the environment and the sow's physiology may also have an influence on the sow's health status, in a domino effect whereby the environment affects the nest-building behaviour and, consequently, the duration of farrowing, which may impact the sow's health. There is evidence that sows with a farrowing duration of ≥4 h are at a high risk of having fever at on the first day after parturition compared with sows with duration of farrowing <4 h (Tummaruk and Sang-Gassanee, 2013).

10.6 Duration of farrowing and influence on sow fertility

The complex interaction between the environmental effects on the physiology of sows at farrowing seems to extend even further to the subsequent fertility of the sow. Recent findings demonstrate that sows with long duration of farrowing (>300 min) have a higher repeat breeding rate (Figure 10.3; Oliviero *et al.*, 2013). This finding can provide valuable information for sow reproductive management. There is no clear explanation yet for this interaction. In free-ranging domestic pigs kept in a semi-natural environment, weaning of the litter is a slow and gradual process, taking between 91 and 126 days post-partum (Jensen and Recén, 1989). On the contrary, in commercial piggeries the lactation period

Table 10.1. Number of stillborn piglets according to housing type (Gu et al.*, 2011; Oliviero* et al.*, 2008a, 2010).*

Housing	Number of stillborn	Average duration of farrowing (min)	Litters
Pen	0.6±0.8	208±58	89
Crate	1.1±1.1	297±130	133

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

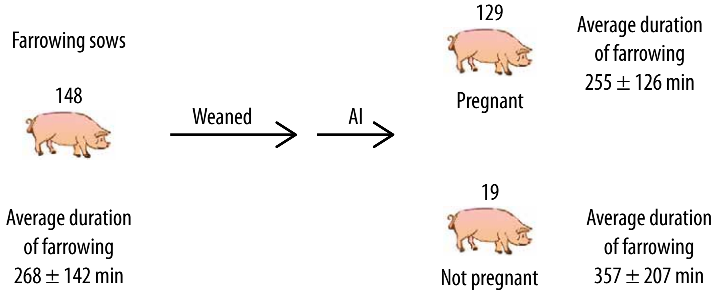


Figure 10.3. Sows which failed to get pregnant at first insemination were having a previous duration of farrowing 100 min longer than those who got pregnant (Oliviero et al.*, 2013).*

is relatively short, usually between 18 and 28 days and the weaning-to-oestrus interval is, on average, 5 days. The interval between parturition and subsequent insemination is therefore much shorter than under natural conditions, which may allow factors that negatively influenced the physiology of parturition to interfere at post-weaning oestrus. Although histological involution of the uterus is completed within 3 weeks after farrowing (Belstra *et al.*, 2005), the period between parturition and subsequent insemination is relatively short. Possibilities as to what physiological mechanisms may be negatively affected by environment include development of follicles, as well as impairment of oxytocin activity and/or oxytocin receptors modulation. However, further research on oxytocin and fat metabolism are needed to substantiate this.

10.6.1 Human intervention into physiology of farrowing: induction of parturition and oxytocin administration during the process of farrowing

Prostaglandins are widely used to induce farrowing in sows. When an injection of prostaglandin is given in the morning, a group of sows is expected to farrow at daytime during the following day. While it is tempting to use prostaglandins to synchronize farrowings of sows in order to ensure supervision of farrowings in the day, the use of prostaglandins for this purpose is known to have risks. Piglets may be born immature since they are induced to be born before term. This is setting greater demands in terms of management of newborn piglets. It is also known that farrowing induction increases the risk of sows showing prolonged interruption of contractions (Smith, 1982) and post-partum dysgalactia syndrome (PDS, Papadopoulos *et al.*, 2010). Furthermore, induction of farrowing increases the risk of certain congenital diseases such as spayleg. The accepted condition in veterinary medicine to recommend farrowing induction is overdue pregnancy, especially in gilts. It is recommended that farrowing be induced if pregnancy exceeds 117 days in gilts.

Oxytocin may be given to stimulate uterine contractions and milk let down. In both cases, a dose of 5-10 IU/sow (IV) may be used as complications are observed, and it can be repeated up to 4-5 times at 2-3 hourly intervals (Martineau, 2005). There should be at least 30 min between two subsequent injections. In fact, in most cases 5 IU appears

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

to be enough to induce milk letdown and by using this low dose it can be injected repetitiously with a reduced risk for side effects. Parenteral administration of synthetic oxytocin is a very efficient way to induce uterine contractions and trigger milk ejection. The intramuscular route of administration is most common but using the intravenous route may further improve the effects. Although efficient and considered safe, repeated use of oxytocin might have some detrimental effects on sows. Indeed, repeated use of oxytocin may be related to poor herd performance (Bilkei Papp, 1994; Ravel *et al.,* 1996) and increased somatic cell counts in milk (Garst *et al.,* 1999). A downside to the use of oxytocin is that it induces placental vasoconstriction, exposing fetuses to hypoxia (Rootwelt, 2012). Oxytocin should therefore not be used as a routine but rather in cases where its use is recommended. The indications generally accepted in veterinary medicine include primary inertia of the uterus and PDS.

10.6.2 Pain management at farrowing

Parturition is a painful process even in the pig, and feeling pain may decrease the interest of the sow towards her piglets. In extreme cases, pain may induce aggressive behaviour. Before farrowing, the sow is showing increased activity. After farrowing, sows lie down, which can be considered as passive behaviour (Malmkvist *et al.*, 2012; Oliviero *et al.*, 2008b; Wallenbeck *et al.*, 2008). Postpartal sows can be affected by roughness of the flooring material, which may cause skin lesions (Norring *et al.,* 2007). In addition, it was shown that the use of non-steroidal agents at farrowing may, to some extent, protect sows from developing skin lesions during early lactation, because of reduced time laying down (Viitasaari *et al.,* 2013). Since endotoxins appear as a major component of clinical sings related to PDS, pharmaceuticals targeted to alleviate endotoxemia may be recommended. Indeed, treatment with non-steroidal agents was shown to have a beneficial effect on health of affected sows. Treatment strategies usually consist of one treatment on the day of parturition, and sometimes a second treatment the following day. Drugs that have been proposed are: flunixin (2 mg/kg) (Cerne *et al.,* 1984), tolfenamic acid (2-4 mg/kg) (Rose *et al.,* 1996), and meloxicam (0.4 mg/kg) (Hirsch *et al.,* 2003). Therefore, appropriate management of pain at farrowing seems appropriate. It is our understanding that under medication is more common than over medication. Whenever a sow refuses to expose her udder towards the piglets in early lactation, pain should be considered as a potential cause of this refusal.

10.7 Effect of environment in early lactation

Maternal behaviour in free-ranging sows is normally performed in an isolated nest that the sow has built during the pre-parturient period (Jarvis *et al.*, 2004). Some hours before farrowing sows show a natural behaviour of nest-building like foraging, rooting and pawing, expressing the desire to build a shelter for protecting their offspring. However, the possibility to perform these natural activities in farrowing crates is limited due to the lack of space, material or both. Provision of a biologically relevant stimuli, such as straw, positively affects the nursing and suckling behaviour of sows and piglets, with reduced termination of sucklings, reduced frequency of foreleg rowing, increased duration of

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

suckling and earlier development of suckling behaviour, which are advantageous for early milk intake by piglets (Herskin *et al.*, 1999). Farrowing crates appear to prohibit interactions between the sow and her piglets to some extent, and the provision of space during parturition could facilitate the performance of maternal behaviour.

Sows kept in farrowing crates with no nest-building material had significantly lower oxytocin concentrations during farrowing than sows kept in loose-housed pens with abundant nest-building materials (Oliviero *et al.*, 2008a). Recent results show that a plentiful supply of nesting materials prior to parturition leads to an increase in sow plasma oxytocin concentrations from 3 days prior to parturition until 7 days postpartum (Yun *et al.*, 2013). This indicates a potential association between nest-building possibilities induced by abundant nesting materials and circulating oxytocin concentrations in peripartal sows. In this study, however, sows housed in loose pens with limited nesting materials did not have greater oxytocin concentrations than sows in confined farrowing crates with an equally limited amount of nesting materials. This indicates that abundant nesting materials may make a greater contribution to increased oxytocin concentrations than non-confinement of loose-housed pens (Yun *et al.*, 2013).

Recent studies revealed that farrowing housing using crates requires extra udder stimulation by the piglets to obtain milk in the early lactation period (Yun *et al.*, 2013). This prolonged udder massage might disturb the sow because it cannot be avoided in the crate, likely resulting in poor welfare because of inadequate coping mechanisms of the sow to this prolonged stress caused by the piglets. Indeed, Oliviero *et al.* (2008a) reported that sows in farrowing crates might have difficulty in denying the nursing activity of piglets, resulting in greater salivary cortisol concentrations when compared with sows in loose-housed pens (Figure 10.2). When sows are provided with abundant nesting material, they show a greater incidence of careful pre-lying behaviour and appear to perform better maternal behaviour in order to care for their offspring (Yun *et al.,* 2013). It can be concluded that provision of suitable space and nesting material before parturition can improve sow welfare by providing opportunities for sows to express their normal behaviour and by reducing potential stresses during the nursing period.

10.8 Body condition, fat metabolism and gut function at farrowing

10.8.1 Body condition and fat metabolism

At the time of farrowing, the sow's metabolism has already switched to a catabolic state, at which point she uses most of her body reserves to produce large quantities of milk (Van den Brand and Kemp, 2005). Rising levels of blood non-esterified fatty acids (NEFA) is a clear indicator of a catabolic state associated with severe body weight loss and low feed intake (Messias de Branganca and Prunier, 1999). It was reported that circulating concentrations of NEFA increase rapidly a few days before farrowing, reaching a peak on the day of parturition (Le Cozler *et al.,* 1999; Oliviero *et al.,* 2009). As the sow approaches farrowing, her body prioritises the impending parturition and begins producing milk.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

On the other hand, feed intake and intestinal function decrease such that the use of external sources of energy is replaced by a catabolic state where there is mobilization of internal reserves of energy such as muscle proteins and NEFA from fat deposits (Oliviero *et al.,* 2009). In this catabolic phase, the energy content of the feed seems less important than the quality of the feed itself. On the other hand, a prolonged feed restriction, albeit mild in terms of quantities, during pregnancy appears to have a negative effect on udder development and mammary gene expression at the end of gestation (Farmer *et al.*, 2014).

As sows approach farrowing, a mild state of constipation is common because the intestine is less active (Kamphues *et al.,* 2000). The sow's body seems to have an inner ability to reduce its intestinal activity in favour of other physiological needs, such as parturition. Studies have also shown that increasing the energy of feeding in late pregnancy can negatively affect the sow's feed intake during early lactation. This reduction in feed intake is thought to be due to reduced glucose tolerance and to insulin resistance caused by excess energy intake during late pregnancy (Fangman and Carlson, 2007).

10.8.2 Intestinal activity and constipation

As mentioned before, a mild state of constipation is common for sows in the very last part of pregnancy and sows often experience a state of constipation just around farrowing (Oliviero *et al.,* 2009). In addition, water absorption in the intestine increases during this phase due to the fluid request resulting from the onset of milk production (Mroz *et al.,* 1995). Offering feed low in volume and fibre can worsen constipation, thus increasing the risk for absorbing bacterial toxins targeting the udder (Smith, 1985). In other studies, constipated sows showed higher rates of mastitis (PDS) than unconstipated sows demonstrating evidence of a direct effect of constipation on udder health (Hermansson *et al.*, 1978; Persson, 1996). During late pregnancy, one common practice in sow feeding aims at reducing the amount of feed offered and increasing the dietary energy. Such concentrated diets usually contain limited amounts of fibre compared with standard pregnancy diets. This practice is done to ensure that sows receive enough energy during late pregnancy to satisfy the needs for upcoming milk production (Einarsson and Rojkittikhun, 1993). This combination of a concentrated and low-fibre diet during a period of physiologically low intestinal activity can lead to severe constipation. Such a mass of solid faeces may create a physical obstacle during birth by pressing on the birth canal, thus resulting in greater difficulty during the expulsive stage (Cowart, 2007). There is a current lack of knowledge as to how much such a state of severe constipation may be a source of intestinal pain for the sows contributing to their declining welfare. Starting five days before expected farrowing, a faecal score can be used to monitor the intestinal activity of sows for 7-10 days, with a daily qualitative evaluation of the faeces. Every morning before the daily cleaning, faeces of the sow should be checked by visual qualitative evaluation. A score value is assigned, ranging from 0 to 5 (Figure 10.4). When the average score is between 1.9 and 3.5 the intestinal activity should be normal, values from 0 to 1.8 indicate different grades of constipation, with a severe condition when the score is under 0.9.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

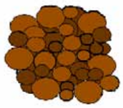
	0	Absence of faeces
	1	Dry and pellet - shaped (unformed)
	2	Between dry and normal (pellet - shaped and formed)
	3	Normal and soft, but firm and well formed
	4	Between normal and wet; still formed, but not firm
	5	Very wet faeces, unformed and liquid

Figure 10.4. Faecal score applicable to evaluate intestinal activity in sows over a week (data from Oliviero et al.*, 2009).*

When higher concentrations of crude fibre are offered in late pregnancy (≥7-10%), the effect of constipation is less severe and sows recover proper intestinal activity faster than when fed diets with lower concentrations of crude fibre (<4%). Recent studies demonstrated that during the period from five days before to five days after farrowing, sows fed a 7% crude fibre diet had an average faecal score of 2.1±1.3 (mean ± SD), compared with an average score of 1.2±1.1 for sows fed a 3% crude fibre diet (Figure 10.5).

In that study, 22% of the sows in the low fibre group exhibited extremely severe constipation (more than five consecutive days without producing faeces), whereas only 5% of the sows in the high fibre group exhibited this condition (Figure 10.6). The average individual daily water consumption was also higher in the high fibre group (29.8±4.9 l) than in the low fibre group (20.2±3.3 l) (Figure 10.7).When sows are lacking an adequate source of fibre in their late pregnancy diet, a mild constipation at farrowing can worsen and develop into severe constipation, and thus negatively influence the duration of farrowing, sow water intake and likely sow welfare.

On days 1 and 5 postpartum, respectively, piglets weighed 1.8±0.3 kg and 2.5±0.3 kg in the high-fibre group, and 1.7±0.3 kg and 2.3±0.5 in the low-fibre group. Piglet weight gain from days 1 to 5 was also greater in the high-fibre group. These results imply a positive effect of feeding sows a high-fibre diet before farrowing on the performance of their suckling piglets.

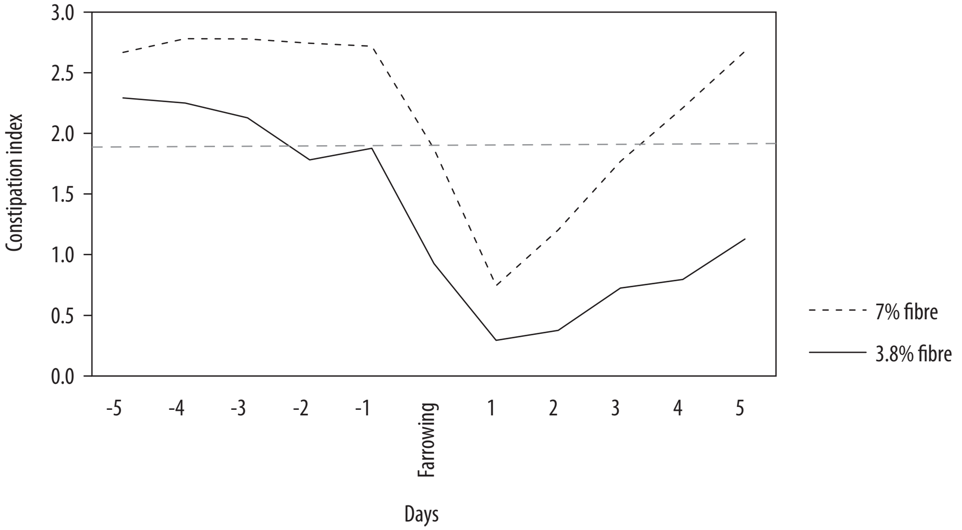


Figure 10.5. Intestinal activity, expressed as constipation index, of sows fed isocaloric diets differing in crude fibre content. Lower values indicate greater constipation state. Normal intestinal activity is considered above the dashed line (Oliviero et al., *2009).*

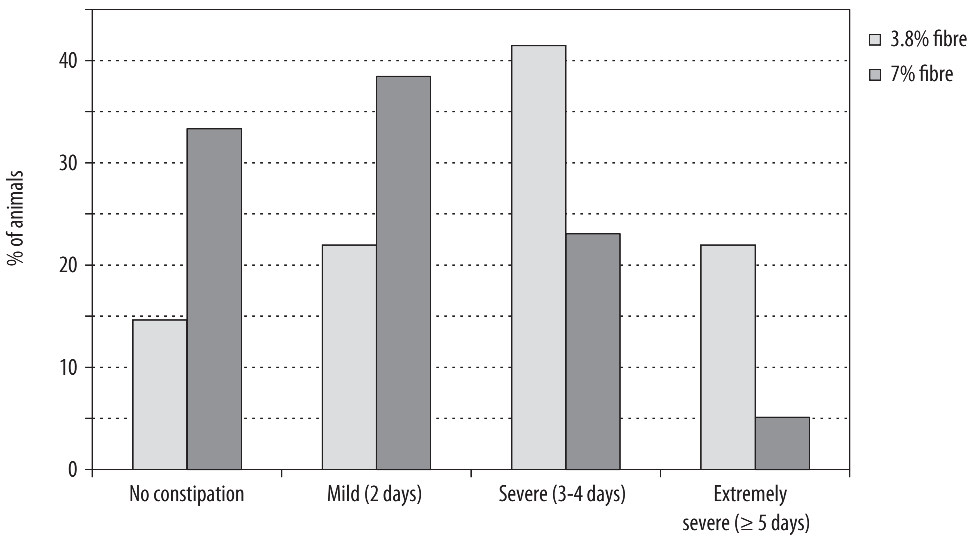


Figure 10.6. Incidence of different levels of constipation during the period from five days before to five days after farrowing in sows fed a 7% FIBRE (n=40) or a 3.8% FIBRE (n=41) diet. Each category consists of various numbers of consecutive days with absence of faeces (Oliviero et al., *2009).*

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

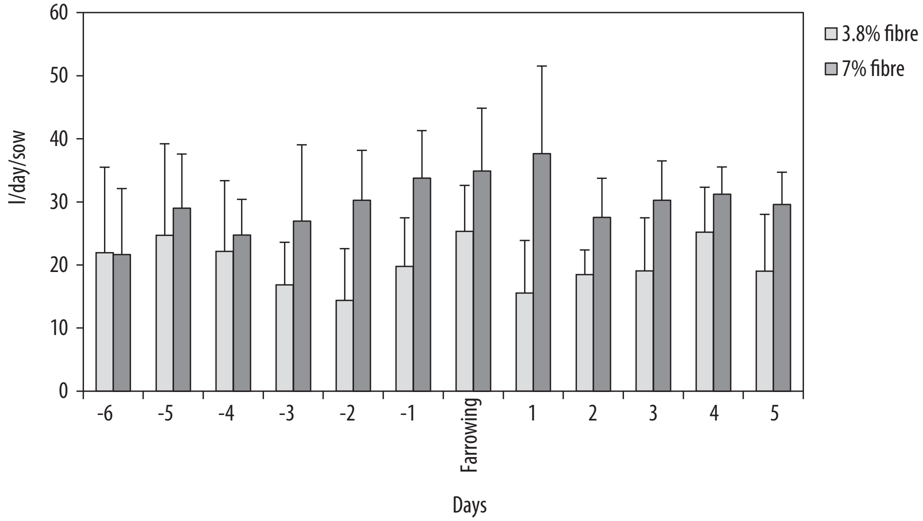


Figure 10.7. Average daily water consumption of sows fed two different levels of crude fibre (Oliviero et al.*, 2009).*

10.8.3 Effects of body condition and constipation on the farrowing process

Higher backfat values were found to be associated with an increased duration of farrowing (Oliviero *et al.*, 2010). In Figure 10.8, all the sows in areas C and D had normal durations of farrowing (<300 min), whereas those in areas A and B had farrowings longer than normal (>300 min). Most of the fatter sows (>17 mm of back-fat) were in area B, whereas most of the thinner sows (<17 mm of backfat) were in area C.

When looking at the correlation between faecal score and the duration of farrowing, the average constipation index score was 2±0.6 (range from 0.3 to 3) and the lower constipation index scores were negatively related with duration of farrowing. Figure 10.9 illustrates that all the sows in areas C and D had a normal farrowing duration (<300 min), whereas those in areas A and B had longer than normal farrowings (>300 min). Many of the constipated sows (<1.9 constipation index score) were in area A, whereas most of the unconstipated sows (>1.9 constipation index score) were in area D (Oliviero *et al.*, 2010).

Cases of severe constipation can be avoided by increasing the amount of dietary fibre in the very last phase of pregnancy. This provision of dietary fibre improves intestinal activity and reduces the degree of constipation. The use of high-fibre diets therefore appears as a beneficial strategy and the role of roughage/substrate at farrowing may also be of importance. Additional roughage could support the sow's nest-building behaviour while at the same time contributing to reduce constipation by providing a readily available source of fibre.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

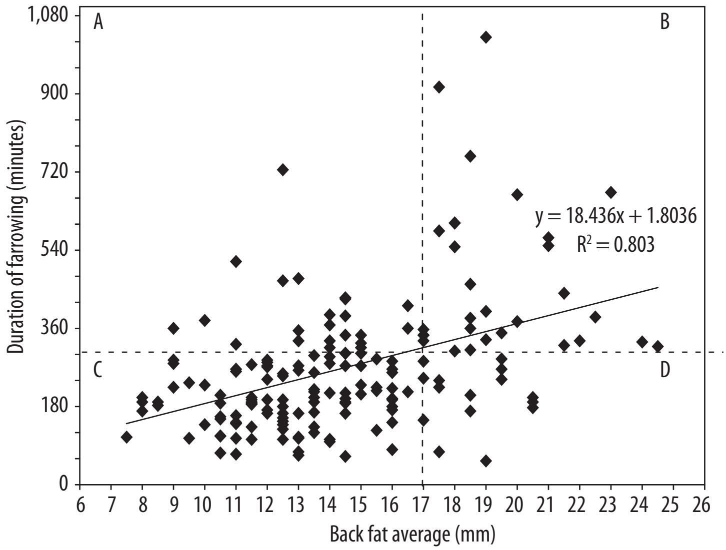


Figure 10.8. Individual sows plotted according to average backfat and duration of farrowing. The horizontal dashed line distinguishes prolonged farrowings (>300 min; areas A, B). The vertical dotted line distinguishes the fatter sows (areas B, D). The solid regression line represents a positive relationship between average backfat and duration of farrowing (Oliviero et al.*, 2010).*

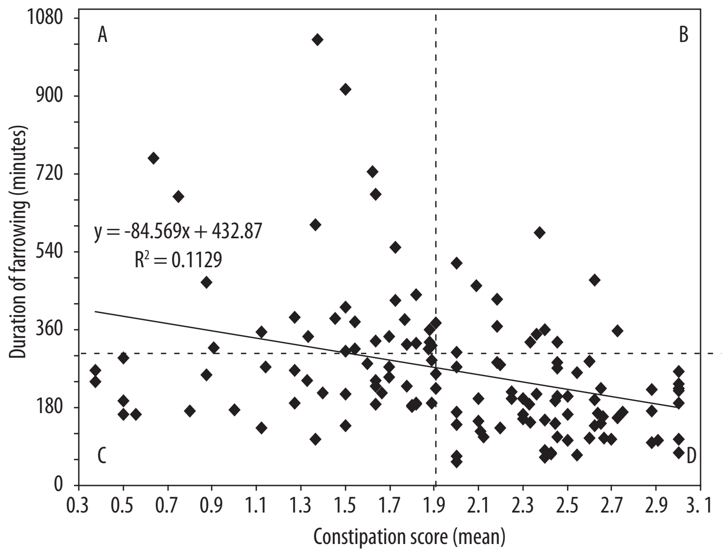


Figure 10.9. Individual sows plotted according to average constipation index score (CI) and duration of farrowing. Low CI values indicate constipated sows, whereas high CI values indicate unconstipated sows. The horizontal dashed line distinguishes prolonged farrowings (>300 min; areas A, B); the vertical dotted line distinguishes constipated sows (areas A, C). The solid regression line represents a negative relationship between the constipation index and the duration of farrowing (Oliviero et al.*, 2010).*

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

10.9 Technology to predict and supervise farrowings

10.9.1 Physiological signs of imminent farrowing

Other than behavioural signs, many clinical signs give clear indications of impending farrowing. Several studies have demonstrated that the sow's body temperature gradually rises to 1-1.5 °C higher than its normal body temperature, from 24-48 h before the onset of farrowing until 12 h before farrowing. This increased body temperature is seen until weaning (Elmore *et al.*, 1979; King *et al.,* 1972). Detection of the sow body temperature is a reliable and fast way would be of help in predicting the onset of farrowing, but also in detecting upcoming diseases which can occur at farrowing and early lactation, such as PDS. However, the traditional rectal temperature detection is not practical. A remote detection method would save time and reduce stress on the animals. Recent studies showed that body surface temperature in swine at various anatomical sites (eye, mammary gland, back of the ear, vulva, and inner part of the ear) can be measured with an infrared camera (IRC) and concluded that infrared thermography may allow routine measurements of body surface temperatures that can be used for early disease detection (Schmidt *et al.*, 2013; Traulsen *et al.*, 2010). Single-time measurements of body-surface temperature with IRC cannot deliver reproducible results under field conditions, but implementing an adapted computer program would improve its use by practitioners as a monitoring tool. For example, IRC monitoring of sow body temperatures over 1 week before farrowing would provide average temperatures for individual sows (Schmidt *et al.,* 2013). In this way either the physiological rise of temperature before parturition or an abnormal rise during farrowing or early lactation could be detected and used to alert farmers of impending farrowing or disease onset.

The respiratory and heart rates also rise a few hours before farrowing, returning to normal after parturition (Kelley and Curtis, 1978). Other well-known signs of impending farrowing are the presence of milk in the udder and a swollen vulva. As described previously, nest-building behaviour is also a very good predictor of upcoming parturition. A few hours before farrowing, the sow's normal activity level can increase three-fold (Hartsock *et al.*, 1997). Observing changes in these signs helps to predict the onset of farrowing in sows, but a more precise collection of data, with the help of technological devices, for example, could provide more accurate predictions.

10.9.2 Predicting the onset of farrowing using movement sensors

The use of a photocell sensor placed at a height of 0.6 m in farrowing crates, makes it possible to detect when the sow is standing up. The average duration of standing is longer in the 24-h interval prior to farrowing compared with all the other 24-h intervals from -120 h until +72 h, relative to farrowing. The mean frequency of standing up and lying down movements is also greater in the 24-h interval prior to farrowing compared with these other intervals (Figure 10.10). Similar findings can be obtained if a force sensor is placed on the floor under the sow. The force sensor recorded a greater number of peaks (activity) in the 24-h interval prior to farrowing than in all the other 24-h intervals monitored.

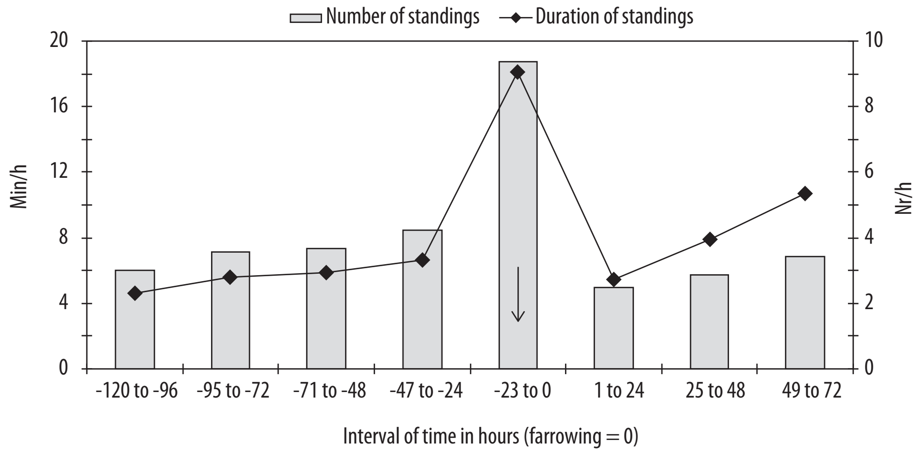


Figure 10.10. Average duration and number of times sows stand per hour in different time intervals before and after farrowing (black arrow) (Oliviero et al.*, 2008b).*

Movement sensors can be of help in predicting the onset of farrowing. Such sensors are cheap and easy to install in piggeries and would provide farmers with useful information that may help them to organise and prevent problems at farrowing. Some studies have demonstrated how human supervision at farrowing can drastically reduce the perinatal mortality of piglets (Andersen *et al.*, 2009; Holyoake *et al.,* 1995; White *et al.,* 1996). Improving the chances of predicting when the sow will give birth would improve the survival of piglets experiencing a dystocic event or suffering from hypothermia or starvation during the first hours after birth. Most sows nowadays farrow without proper assistance in environments that often fail to provide them with the tools they require to express their physiologically-driven behavioural needs. More investments are needed to improve the quality of accommodation for sows at farrowing and to reduce perinatal mortality due to lack of supervision.

10.9.3 Implications for the pig industry

Automation is assuming a more and more important role in animal husbandry today. Although, the excessive use of machines and computers to manage the relationship between livestock and humans should be avoided, modern technology can be useful in improving the monitoring of physiological, behavioural and clinical signs in production animals. This is especially the case considering the recent preference of animal production for very large herds with ever increasing numbers of animals per unit. An automated system that could monitor peripartal sows in the herd and, with the help of specialized software, sound alarms when necessary, could prove useful. Oliviero *et al.* (2008b) demonstrated how it is possible to monitor behavioural changes that signal impending farrowing. It would be similarly possible to monitor important physiological and clinical signs occurring in the peripartal period. The temperature of newborn piglets is a critical factor for their survival in the first postnatal hours (Le Dividich and Noblet, 1983; Tuchscherer *et al.,* 2000).

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

Further investigation on the use of remote devices, such as thermo-cameras, is needed to rapidly and successfully check the body temperature of piglets and sows.

10.10 Conclusions

Recent results on technologies applied to farrowing surveillance, may encourage farmers to view farrowing more from the perspective of the sow and piglets. Benefits of using open crates for farrowing are significant and denote how welfare of the animals often correlates positively with economic benefit, as demonstrated by the lower number of stillborn piglets in this type of housing. In many circumstances, it is possible to allow sows to farrow in an open crate so that they can better express their nest-building behaviour, and only after farrowing, to close the crate to protect the piglets from crushing. Adding roughage a few days before farrowing would provide the sow with a substrate to better express nest-building behaviour and, in the case of straw, would also provide a source of fibre which can alleviate the state of constipation that arises around farrowing. Management of farrowing in terms of pharmacological interventions should be carefully considered and planned. Use of hormone preparations such as prostaglandins and oxytocin may have adverse effects that need to be taken into account, therefore routine use of these hormones and their analogues is not a wise strategy. Pain management, however, often appears as a forgotten element in the management of farrowing and there is room for improvement. Whenever abnormal nursing behaviour or refusal to nurse is observed, pain should be considered as a potential cause and pain medication may be indicated. Constipation at farrowing should be of greater concern to farmers, and results support the importance of its prevention by increasing the use of dietary fibre during late pregnancy. Looking more carefully for signs of constipation in the herd can be facilitated with individual daily screening according to a qualitative faecal scoring. In the farrowing unit, daily evaluation of the sow's faeces, especially recording days with absence of faeces, can provide the farmer and veterinarian with a clear picture of the individual sow's state of constipation and allow to correct it in a timely fashion. The sow's water intake in very late pregnancy, farrowing and lactation is also a very important issue. Recent findings showed that sows fed a high-fibre diet drank more water and reared heavier piglets during their first week after birth, confirming how the adequate availability of water during this period is essential.

References

Algers, B., 1994. Health, behaviour and welfare of outdoor pigs. Pig News Information 15: 113-115.

Algers, B. and Uvnäs-Moberg, K., 2007. Maternal behavior in pigs. Hormones and Behaviour 52: 78-85.

Andersen, I., Haukvik, I. and Bøe, K., 2009. Drying and warming immediately after birth may reduce piglet mortality in loose-housed sows. Animal 3: 592-597.

Anderson, L.L., 2000. Reproductive cycle of pigs. In: Hafez, E.S.E. and Hafez, B. (eds.) Reproduction in farm animals – VII edition. Lippincott, Philadelphia, PN, USA, pp. 189-190.

Aumaitre, A. and Le Dividich, J., 1984. Improvement of piglet survival rate in relation to farrowing systems and conditions. Annales de Recherches Vétérinaires 15: 173-179.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

Belstra, B., Flowers, W., Croom, W., De Groot, J. and See, M., 2005. Urinary excretion of collagen degradation markers by sows during postpartum uterine involution. Animal Reproduction Science 85:131-145.

Bilkei Papp, G., 1994. Perinatal losses general condition of sows III experiences obtained with prednisolone pre-treatment. Magy Allatorv Lap 49: 680-683.

Castrén, H., Algers, B., De Passillé, A.M., Rushen, J. and Uvnäs-Moberg, K., 1994. Nest-building in sows in relation to hormone release. Applied Animal Behaviour Science 40: 74-75.

Castrén, H., Algers, B., De Passillé, A.M., Rushen, J. and Uvnäs-Moberg, K., 1993. Early ejection, prolonged parturition and periparturient oxytocin release in the pig. Animal Production 57: 465-471.

Cerne, F., Jerkovic, I. and Debeljak, C., 1984. Influence of Finadyne on some clinical signs of MMA. In: Proceedings of the 8th International Pig Veterinary Society Congress. Ghent, Belgium, pp. 290.

Cowart, R.P., 2007. Parturition and dystocia in swine. In: Youngquist, R.S. and Threlfall, W.R., (eds.) Large animal theriogenology. Saunders Elsevier, St. Louis, MO, USA, pp. 778-784.

Cronin, G.M., Simpson, G.J. and Hemsworth, P.H., 1996. The effects of the gestation and farrowing environments on sow and piglet behaviour and piglet survival and growth in early lactation. Applied Animal Behaviour Science 46: 175-192.

Damm, B.I., Lisborg, L., Vestergaard, K.S. and Vanicek, J., 2003. Nest-building behavioural disturbances and heart rate in farrowing sows kept in crates and Schmid pens. Livestock Production Science 80: 175-187.

Damm, B.I., Vestergaard, K.S., Schrøder-Petersen, D.L. and Ladewig, J., 2000. The effects of branches on prepartum nest-building in gilts with access to straw. Applied Animal Behaviour Science 69: 113-124.

Edwards, S.A. and Fraser, D., 1997. Housing systems for farrowing and lactation. Pig Journal 39: 77-89.

Einarsson, S. and Rojkittikhun, T., 1993. Effects of nutrition on pregnant and lactating sows. Journal of Reproduction and Fertility Supplement 48: 229-239.

Ellendorff, F., Taverne, M., Elsaesser, F., Forsling, M., Parvizi, N., Naaktgeboren, C. and Smidt, D., 1979. Endocrinology of parturition in the pig. Animal Reproduction Science 2: 323-334.

Elmore, R.G., Martin, C.E., Riley, J.L. and Littledike, T., 1979. Body temperatures of farrowing swine. Journal of the American Veterinary Medical Association, 174: 620-622.

Fangman, T.J. and Carlson, M.S., 2007. Disease of the puerperal period.. In: Youngquist, R.S. and Threlfall W.R. (eds.) Large animal theriogenology 2. Saunders Elsevier, St. Louis, MO, USA, pp. 792-793.

Farmer, C., Palin, M.F. and Martel-Kennes, Y., 2014. Impact of diet deprivation and subsequent overallowance during gestation on mammary gland development and lactation performance. Journal of Animal Science 92: 141-151.

Fraser, D., 1990. Behavioural perspectives on piglet survival. Journal of Reproduction and Fertility 40: 355-370.

Garst, A.S., Ball, S.F., Williams, B.L., Wood, C.M., Knight, J.W., Moll, H.D., Aardema, C.H. and Gwazdauskas, F.C., 1999. Influence of pig substitution on milk yield, litter weights, and milk composition of machine milked sows. Journal of Animal Science 77: 1624-1630.

Gilbert, C.L., Goode, J.A. and MacGrath, T.J., 1994. Pulsatile secretion of oxytocin during parturition in the pig: temporal relationship with foetal expulsion. Journal of Physiology 475: 129-137.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

Gu, Z., Gao, Y., Lin, B., Zhong, Z., Liu, Z., Wang, C. and Li, B., 2011. Impacts of freedom farrowing pen design on sow behaviours and performance. Preventive Veterinary Medicine 102: 296-303.

Gustafsson, M., Jensen, P., De Jonge, F.H., Illman, G. and Špinka, M., 1999. Maternal behaviour of domestic sows and crosses between domestic sows and wild boar. Applied Animal Behaviour Science 65: 29-42.

Hales, J., Moustsen, V.A., Nielsen, M.B. and Hansen, C.F., 2014. Higher preweaning mortality in free farrowing pens compared with farrowing crates in three commercial pig farms. Animal 8: 113-120.

Hansen, K.E. and Curtis, S.E., 1980. Prepartal activity of sows in stall or pen. Journal of Animal Science 51: 456-460.

Hartsock, T.G. and Barczewski, R.A., 1997. Prepartum behaviour in swine: effects of pen size. Journal of Animal Science 75: 2899-2903.

Hermansson, I., Einarsson, S., Larsson, K. and Backstrom, L., 1978. On the agalactia post partum in the sow. A clinical study. Nordisk Veterinaer Medicin 30: 465-473.

Herskin, M.S., Jensen, K.H. and Thodberg, K., 1999. Influence of environmental stimuli on nursing and suckling behaviour in domestic sows and piglets. Animal Science 68: 27-34.

Hirsch, A.C., Philipp, H. and Kleemann, R.. 2003. Investigation on the efficacy of meloxicam in sows with mastitis-metritis-agalactia syndrome. Journal of Veterinary Pharmacology and Therapeutics 26: 355-360.

Holyoake, P.K., Dial, G.D., Trigg, T. and King, V.L., 1995. Reducing pig mortality through supervision during the perinatal period. Journal of Animal Science 73: 3543-3551.

Jarvis J., Reed B.T., Lawrence A.B., Calvert S.K. and Stevenson J., 2004. Peri-natal environmental effects on maternal behaviour, pituitary and adrenal activation, and the progress of parturition in the primiparous sow. Animal Welfare 13: 171-181.

Jarvis, S., Lawrence, A.B., McLean, K.A., Deans, L.A., Chirnside, J. and Calvert, S.K., 1997.

Jarvis, S., Reed, B.T., Lawrence, A.B., Calvert, S.K. and Stevenson, J., 2002. Pituitary-adrenal activation in pre-parturient pigs (*Sus scrofa*) is associated with behavioural restriction due to lack of space rather than nesting substrate. Animal Welfare 11: 371-384.

Jensen, P., Broom, D.M., Csermely, D., Dijkhuizen, A.A., Hylkema, S., Madec, F., Stamataris, C. and Von Borell, E., 1997. The welfare of intensively kept pigs. Report of the Scientific Veterinary Committee of the European Union, pp. 31-34.

Jensen, P. and Recén, B., 1989. When to wean – observations from free-ranging domestic pigs. Applied Animal Behaviour Science 23: 49-60.

Kamphues, J., Tabeling, R. and Schwier, S., 2000. Effects of different feeding and housing conditions on dry matter content and consistency of faeces in sows. Deutsche tierärztliche Wochenschrift 107: 380.

Kelley, K.W. and Curtis S.E., 1978. Effects of heat stress on rectal temperature, respiratory rate and sitting and standing activity rates in peripartal sows and gilts. Journal of Animal Science 46: 356.

Kemp, B. and Soede, N.M., 2012. Reproductive issues in welfare-friendly housing systems in pig husbandry: a review. Reproduction in Domestic Animal 47(5): 51-57.

Kerr, J. C. and Cameron, N.D., 1995. Reproductive performance of pigs selected for components of efficient lean growth. Animal Science 60: 281-290.

Kindahl, H., Alonso, R., Cort, N. and Einarsson, S., 1982. Release of prostaglandin F2α during parturition in the sow. Zentralblatt für Veterinärmedizin 29: 504-510.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

King, G.J., Willoughby, R.A. and Hacker, R.R., 1972. Fluctuations in rectal temperature of swine at parturition. Canadian Veterinary Journal 13: 72-74.

Lawrence, A.B., Petherick, J.C., McLean, K.A., Deans, L.A., Chirnside, J., Vaughan, A., Clutton, E. and Terlouw, E.M.C., 1994. The effect of environment on behaviour, plasma cortisol and prolactin in parturient sows. Applied Animal Behaviour Science 39: 313-330.

Le Cozler, Y., Beaumal, V., Neil, M., David, C. and Dourmad, J.Y., 1999. Changes in the concentrations of glucose, non-esterified fatty acids, urea, insulin, cortisol and some mineral elements in the plasma of the primiparous sow before, during and after induced parturition. Reproduction Nutrition Development 39: 161-169.

Le Dividich, J. and Noblet, J., 1983. Thermoregulation and energy metabolism in the neonatal pig. Annales de recherches vétérinaires 14: 375-381.

Malmkvist, J., Pedersen, L.J., Kammersgaard, T.S. and Jørgensen, E., 2012. Influence of thermal environment on sows around farrowing and during the lactation period. Journal of Animal Science 90: 3186-3199.

Martineau, G.P., 2005. Postpartum dysgalactia syndrome and mastitis in sows. In: Kahn C.M. (ed.) Reproduction. The Merck Veterinary Manual (9th ed.). Merck Co, Inc, Whitehouse Station, NJ, USA, pp: 1134-1137.

Messias de Branganca, M. and Prunier, A., 1999. Effects of low feed intake and hot environment on plasma profiles of glucose, nonesterified fatty acids, insulin, glucagon, and IGF-1 in lactating sows. Domestic Animal Endocrinology 16: 89-101.

Meulen, J., Helmond, F.A., Oudenaarden, C.P.J. and Van der Meulen, J., 1988. Effect of flushing of blastocysts on days 10-13 on the life-span of the corpora lutea in the pig. Journal of Reproduction and Fertility 84: 157-162.

Mroz, Z., Jongbloed, A.W., Lenis, N.P. and Vreman, K., 1995. Water in pig nutrition: physiology, allowances and environmental implications. Nutrition Research Reviews 8: 137-164.

Norring, M., Valros, A., Munksgaard, L., Puumala, M., Kaustell, K.O. and Saloniemi, H., 2007. The development of skin, claw and teat lesions in sows and piglets in farrowing crates with two concrete flooring materials. Acta Agriculturae Scandinavica, Section A – Animal Science 56: 148-154.

Oliviero, C., Heinonen, M., Valros, A. and Peltoniemi, O.A.T., 2010. Environmental and sow-related factors affecting the duration of farrowing. Animal Reproduction Science 119: 85-91.

Oliviero, C., Heinonen, M., Valros. A., Hälli, O. and Peltoniemi, O.A.T., 2008a. Effect of the environment on the physiology of the sow during late pregnancy, farrowing and early lactation. Animal Reproduction Science 105: 365-377.

Oliviero, C., Kokkonen, T., Heinonen, M., Sankari, S. and Peltoniemi, O.A.T., 2009. Feeding sows a high-fibre diet around farrowing and early lactation: impact on intestinal activity, energy balance-related parameters and litter performance. Research in Veterinary Science 86: 314-319.

Oliviero, C., Kothe, S., Heinonen, M., Valros, A. and Peltoniemi. O., 2013. Prolonged duration of farrowing is associated with subsequent decreased fertility in sows. Theriogenology 79: 1095-1099.

Oliviero, C., Pastell, M., Heinonen, M., Heikkonen, J., Valros, A., Ahokas, J., Vainio, O. and Peltoniemi, O.A.T., 2008b. Using movement sensors to detect the onset of farrowing. Biosystems Engineering 100: 281-285.

Osterlundh, I., Holst, H. and Magnusson, U., 1998. Hormonal and immunological changes in blood and mammary secretion in the sow at parturition. Theriogenology 50: 465-477.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

Papadopoulos, G., Vanderhaege, C., Janssens, G., Dewulf, D. and Maes, D., 2010. Risk factor associated with *post partum* dysgalactia syndrome in sows. The Veterinary Journal 184: 167-171.
Persson, A., 1996. Lactational disorders in sows, with special emphasis on mastitis. In: Proceeding of the 47th meeting of the European association for animal production. Lillehammer, Norway, pp. 26-29.
Phillips, P.A. and Fraser, D., 1993. Developments in farrowing housing for sows and litters. Pigs News Info. 14: 51-55.
Ravel, A., D'Allaire, S. and Bigras Poulin, M., 1996. Influence of management, housing and personality of the stockperson on preweaning performances on independent and integrated swine farms in Québec. Preventive Veterinary Medicine 29: 37-57.
Roehe, R., 1999. Genetic determination of individual birthweight and its association with sows' productivity traits using Bayesian analysis. Journal of Animal Science 77: 330-343.
Rootwelt, V., 2012. Piglet stillbirth and neonatal death. PhD Thesis, Norwegian School of Veterinary Medicine, Oslo, Norway.
Rose, M., Schnurrbusch, U. and Heinrotzi, H.. 1996. The use of cequinome in the treatment of pig respiratory disease and MMA syndrome. Proceedings of the International Pig Veterinary Society Congress 14: 317-317.
Schmidt, M., Lahrmann, K.H. and Ammon, C., 2013. Assessment of body temperature in sows by two infrared thermography methods at various body surface locations. Journal of Swine Health Production 21: 203-209.
Smith, B.B., 1985. Pathogenesis and therapeutic management of lactation failure in periparturient sows. Compendium Continuing Education Practice 7: 523.
Smith, W.C., 1982. The induction of parturition in sows using prostaglandin F2alpha. New Zealand Veterinary Journal 30: 34-37.
Sorensen, D., Vernersen, A. and Andersen, S., 2000. Bayesian analysis of response to selection: a case study using litter size in Danish Yorkshire pigs. Genetics 156: 283-295.
The effect of environment on behavioural activity, ACTH, beta-endorphin and cortisol in prefarrowing gilts. Animal Science 65: 465-472.
Thodberg, K., Jensen, K.H., Herskin, M.S. and Jørgensen, E., 1999. Influence of environmental stimuli on nest-building and farrowing behaviour in domestic sows. Applied Animal Behaviour Science 63: 131-144.
Traulsen, I., Naunin, K., Müller, K. and Krieter, J., 2010. Application of infrared thermography to measure body temperature of sows. Züchtungskunde 82: 437-446.
Tuchscherer, M., Puppe, B., Tuchscherer, A. and Tiemann, U., 2000. Early identification of neonates at risk: traits of newborn piglets with respect to survival. Theriogenology 54: 371-388.
Tummaruk, P. and Sang-Gassanee, K., 2013. Effect of farrowing duration, parity number and the type of anti-inflammatory drug on postparturient disorders in sows: a clinical study. Tropical Animal Health and Production 45: 1071-1077.
Van den Brand, H. and Kemp, B., 2005. Dietary fat and reproduction in the post partum sow. In: Ashworth, C.J. and Kraeling, R.R., (eds.) Control of pig reproduction VII, Nottingham University Press, Nottingham, UK, pp. 177-189.
Vestergaard, K. and Hansen, L.L., 1984. Tethered versus loose sows: ethological observations and measures of productivity. I. Ethological observations during pregnancy and farrowing. Annales de Recherches Vétérinaires 15: 245-256.

https://www.wageningenacademic.com/doi/pdf/10.3920/978-90-8686-803-2_10 - Tuesday, December 03, 2019 7:00:07 AM - IP Address:200.110.189.224

Viitasaari, E., Hänninen, L., Heinonen, M., Raekallio, M., Orro, T., Peltoniemi, O. and Valros, A., 2013. Effects of post-partum administration of ketoprofen on sow health and piglet growth. Veterinary Journal 198: 153-157.

Wallenbeck, A., Rydhmer, L. and Thodberg, K., 2008. Maternal behaviour and performance in first-parity outdoor sows. Livestock Science 116: 216-222.

White, K.R., Anderson, D.M. and Bate, L.A., 1996. Increasing piglet survival through an improved farrowing management protocol. Canadian Journal of Animal Science 76: 491-495.

Yun, J., Swan, K.M., Vienola, K., Farmer, C., Oliviero, C., Peltoniemi, O. and Valros, A., 2013. Nest-building in sows: effects of farrowing housing on hormonal modulation of maternal characteristics. Applied Animal Behaviour Science 148: 77-84.