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The effect of farm management, housing conditions and maternal behaviour during lactation on piglet behaviour and mortality

Ph.D. thesis

Author: **Ing. Michala Melišová**

Supervisor: **Prof. Ing. Luděk Bartoš , DrSc.**

(1) Department of Husbandry and Ethology of Animals, Czech University of Life Sciences in Prague; (2) Department of Ethology, Institute of Animal Science, Prague Uhříněves

Supervisor – specialist: **RNDr. Gudrun Illmann, CSc.**

Department of Ethology, Institute of Animal Science, Prague Uhříněves

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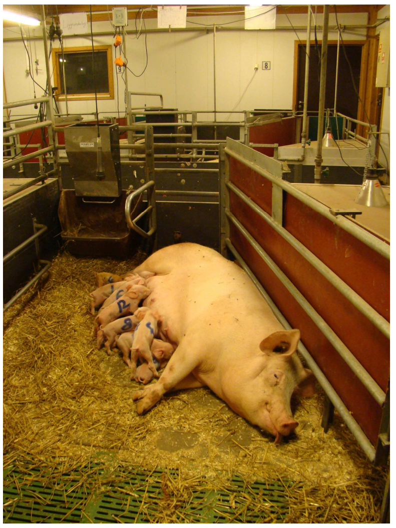
Declaration

I declare that I have composed this Ph.D. thesis on my own and that I have cited all sources and literature used. Either this thesis or a substantial part of it has been submitted for no other qualification. Printed and an electronic version of the work is literally identical.

Prague, September 28th 2012 Michala Melišová

„The greatness of a nation and its moral progress can be judged by the way its animals are treated."

Mahatma Gandhi

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Abstract

This thesis focuses on the effect of farm management, housing conditions and maternal behaviour during lactation on piglet behaviour and mortality. Piglet mortality represents regardless of the housing system for farrowing sows serious economical and welfare issue on all commercial pig farms. The thesis is based on three papers with IF which focused on various treatments in order to reduce piglet mortality. In addition, conclusions from a review addressing among others the effect of housing system on piglet mortality is included in the thesis. All experiments were conducted on individually loose-housed sows in Norway in 2009 which provide better welfare to sows and piglets but are by pig breeders traditionally considered unable to compete with crated systems in terms of higher piglet mortality. The first study focused on six different management treatments at the time of farrowing as drying piglets, placing them at the udder or creep area and their combination (dry + udder, dry + creep area) and control treatment on latency to first suckle, heat loss, weight gain and postnatal mortality. The differences in piglet mortality between various treatments were not clearly distinct, however when merging all six treatments into three classes (control, treatments including drying and treatments not including drying) there was higher postnatal mortality in treatments which does not include piglet drying compared to control and treatments including piglet drying after birth. Large litter sizes resulted in a higher postnatal mortality in all treatments. Regardless of treatment, several piglet-related factors were found to be highly important for postnatal mortality, such as the number of functional teats per piglet, birth weight, the latency from birth to first suckle and rectal temperature at 2 hours after birth. In the second study, several creep area features attractive to piglets to increase the heat conserving capacity in the creep area (an insulated and soft bedding in the creep area and an equal creep area plus an additional wall as insulation; both compared to control) were used to attempt to increase time spent by piglets in the creep area the first two days after birth (i.e. creep area should provide suitable microclimate and, as commonly assumed, protect piglets from maternal crushing). Furthermore, we investigated whether increased time spent in the creep area would really affect piglet crushing and mortality. Improving the thermal comfort and increase the layer of bedding in the creep area did not increase time spent away from the sow, nor did it reduce piglet mortality. The quality of the creep area thus appears to have little impact on piglet survival. The third study focused on the impact of sow–piglet communication during pre-lying behaviour (sow vocalization, sniffing and nudging piglets) on piglet location before the sow was lying down and on the incidence of piglet crushing. In contrast to what we predicted, vocalization and sniffing increased the proportion of piglets (out of the litter size) in the predefined danger zone (area in a close proximity from the sow where higher incidence of piglet crushing was expected); nudging did not have any effect. Thus the more sows communicated with piglets, the more the piglets were attracted to stay in close proximity to the sow, however there was no association detected between sow pre-lying communication and piglet crushing. In summary, these results should be taken into account for practical use in order to reduce piglet mortality on commercial pig farms. Farrowing should be attended by the barn staff that would dry the piglets after birth, inspect functional teats and help the piglets to get the first milk intake as soon as possible after birth. Furthermore, piglets' strong natural need to keep close to the mother in the first few days after the farrowing should be implemented when designing new housing systems for farrowing sows (based on these results new farrowing pens without separated creep area for piglets are currently tested on a larger scale for future commercial use in Norway). There is increased evidence from literature suggesting competitiveness of loose farrowing systems with crated systems in terms of piglet mortality.

Key words: piglet mortality, farrowing pens, crushing, management routines, creep area, maternal behaviour

Abstrakt

Tato disertační práce je zaměřena na vliv managementu, ustájení a mateřského chování během laktace na chování a mortalitu selat, která - bez rozdílu v typu ustájení - představuje vážný ekonomický a welfarový problém ve všech komerčních chovech prasat. Tato práce vychází ze tří článků s IF, jejichž cílem bylo snížit mortalitu selat. Dále zahrnuje poznatky prezentované jako review v časopise Veterinářství, který se, kromě jiného, soustředí na vliv ustájení na mortalitu selat. Všechny experimenty byly provedeny na prasnicích a selatech ustájených individuálně ve volných porodních kotcích v Norsku v roce 2009. Volné ustájení poskytuje prasnicím a selatům lepší welfare, avšak chovatelé prasat toto ustájení považují tradičně za nekonkurenceschopné z důvodů vyšší mortality selat. První experiment se zaměřil na 6 různých poporodních ošetření selat, které byly provedeny ihned po porodu, jako je osušení selat, přiložení selat ke strukům, vložení selat do teplého vyhřívaného hnízda, jejich kombinace (usušení + ke strukům, usušení + do hnízda) a kontroly, na latenci prvního napití se kolostra, tepelné ztráty, váhový přírůstek a na mortalitu selat. Vliv jednotlivých ošetření selat na mortalitu selat nebyl jednoznačný, přesto pokud 6 ošetření rozdělíme do 3 skupin (kontrola, ošetření zahrnující osušení selat a ošetření bez osušení selat), pak byla nalezena vyšší mortalita u selat, které nebyly po porodu osušeny v porovnání s kontrolou a těmi selaty, které osušeny byly. Se zvyšujícím se počtem selat ve vrhu také došlo ke zvýšení mortality selat u všech ošetření. Nicméně, bez rozdílu, které ošetření po porodu bylo provedeno, byly zjištěny faktory, které výrazně ovlivňují mortalitu selat, jako je počet funkčních struků na každé sele ve vrhu, porodní váha, latence prvního napití se kolostra a rektální teplota 2 hodiny po porodu. Ve druhé studii jsme se soustředily na kvalitu hnízda pro selata a jeho atraktivitu ve smyslu tepelného komfortu (hnízdo bylo vystláno měkkou a suchou podestýlkou v porovnání se stejným hnízdem, které bylo navíc chráněno stěnou jako izolací; obě hnízda byla porovnána s kontrolou) s cílem motivovat selata, aby strávila v hnízdě více času během prvních dvou dnů po porodu (tj. hnízdo poskytne selatům vhodné mikroklima, a dle všeobecně rozšířeného předpokladu, chrání selata před zalehnutím matkou). Dále jsme zkoumali, zda toto proporcionální navýšení množství času stráveného selaty v hnízdě opravdu ovlivňuje zalehání selat a mortalitu po porodu. Zlepšení tepelného komfortu hnízda však neovlivnilo množství času, který selata strávila mimo oblast blízkosti matky (tj. v hnízdě), ani nedošlo ke snížení mortality selat. Kvalita hnízda se tak jeví jako nepodstatná ve smyslu přežití selat po porodu. Ve třetí studii jsme se zaměřili na komunikaci prasnice se selaty bezprostředně před ulehnutím (vokální komunikace, očichávání a naso-nasální kontakty) na pravděpodobnost výskytu selat v blízkosti matky v okamžiku lehání, a na vliv tohoto chování na mortalitu selat. Na rozdíl od našich předpokladů, s vyšší frekvencí vokalizace prasnice a očichávání selat se zvýšila pravděpodobnost výskytu selat v tzv. nebezpečné zóně (oblast v bezprostřední blízkosti matky, kde byl očekáván zvýšený výskyt zalehnutí selat prasnicí). Naso-nasální kontakty neměly vliv na pravděpodobnost výskytu selat v blízkosti matky. Shrnuto, čím více prasnice se selaty komunikovala, tím více selat bylo přítomno v její bezprostřední blízkosti, nicméně vliv komunikace prasnice a mortality selat potvrzen nebyl. Závěrem, výsledky uvedené výše jsou cenné pro praxi a měly by být vzaty v úvahu za účelem snížení mortality selat v komerčních chovech prasat. Ošetřovatel by měl být přítomný u porodu prasnic, ihned po porodu selata osušit, zkontrolovat funkční struky a přikládat selata ke strukům, aby se napila kolostra co možná nejdříve po porodu. Mimoto, silná potřeba selat držet se v blízkosti matky během prvních dnů po porodu, by měla být respektována při vývoji nových typů porodních boxů pro prasnice (na základě těchto výzkumů probíhá v současné době již ve větším měřítku testování nového ustájení, kde selata nejsou separována od matky v hnízdě, s cílem využít následně toto ustájení v komerčních chovech prasat). Množství studií přinášejících závěry o srovnatelné míře mortality selat ve volném a klecovém ustájení poukazuje na konkurenceschopnost volného ustájení.

Klíčová slova: mortalita selat, volné ustájení, management, hnízdo pro selata, mateřské chování

List of original papers

This thesis is based on the following papers (Paper I-IV) which are referred to in the text by their roman numerals:

- **Paper I:** Vasdal G., Ostensen I., **Melišová M**., Bozděchová B., Illmann G., Andersen I.L. 2011. Management routines at the time of farrowing — effects on teat success and postnatal piglet mortality from loose housed sows. Livestock Science. 136. 225-231.

- **Paper II:** Vasdal G., Glaerum M., **Melišová M.,** Boe K. E., Broom D. M., Andersen I. L. 2010. Increasing the piglets' use of the creep area - A battle against biology? Applied Animal Behaviour Science.125. 96-102.

- **Paper III: Melišová M.**, Illmann G., Andersen I.L., Vasdal G., Haman J. 2011. Sow pre-lying communication or good piglet condition prevent piglets from getting crushed? Applied Animal Behaviour Science. 134. 121 – 129.

- **Paper IV: Melišová M.,** Illmann G., Chaloupková H. 2012. Ustájení prasnic během laktace: welfare prasnic a mortalita selat. Veterinářství. 7. 417 – 419.

1. Introduction

1.1. General introduction

This thesis provides new knowledge about the effect of farm management, housing environment and maternal behaviour on piglet behaviour and early piglet mortality. It is based on three published papers with IF and one article published in the journal reviewed by scientific commission (Veterinářství). All studies were carried out in domestic pigs *(Sus scrofa f. domestica).*

Domestic pigs are descendants of the wild boar (*Sus scrofa*), a geographically widely distributed artiodactyl species belonging to the family *Suidae* (Špinka, 2009). As far as we know, no single behavioural pattern of the maternal behaviour has disappeared from the wild boar repertoire during the domestication process (Gustafsson et al., 1999). Therefore, behaviour of wild boar, feral pigs and domestic pigs kept in natural conditions informs us about the behavioural needs of pigs and also helps us to understand the structure and the function of behavioural patterns whose purpose is difficult to see within the barren conditions of modern intensive indoor systems (Špinka, 2009).

World pig meat production has nearly doubled over the last 20 years and more than 1 billion domestic piglets are born every year worldwide (Cameron, 2000). There are more than 15 million sows and 40 million piglets in the European Union (EU 27; Eurostat 2010). In the Czech Republic the number of sows in contrary actually decreased within the last two decades from around 330 thousands in 1990 to 122 thousands in 2009, however with 23.7 liveborn piglets per sow yearly (SCHP, 2010), which makes almost 3 million piglets born every year (Agroweb, 2012), it is still an industry of a very high importance. In Norway, where the experiments included in the present thesis were conducted, every year more than 1 million piglets are born (Norsvin, 2008).

Piglet mortality represents a serious economical and welfare problem in all housing systems for lactating sows and ranges from 10 up to 20 % (Weary et al., 1996; Marchant et al., 2001; Edwards, 2002; Damm et al., 2005; Johnson et al., 2007). In the Czech Republic live-born piglet mortality is around 10.9 % (ČSÚ, 2011). In Norway 14.8 % live-born piglets die before weaning (Norsvin, 2008). Piglet mortality is the highest within first 3 days post-partum (pp) and is caused by maternal crushing, starvation, hypothermia and their combination (Marchant et al., 2000; Edwards, 2002). Prenatal factors, management around farrowing, housing environment and maternal behaviour all play an important role in piglet survival (e.g. Andersen et al., 2005; Baxter et al., 2008; Andersen et al., 2009). The vast majority of lactating sows on commercial pig farms are since 1960s housed in farrowing crates which provide unsatisfactory living conditions for the sows as restriction of movement, nest-building and communication of piglets (e.g. reviewed by Barnett et al., 2001 and Wechsler and Weber, 2007) but that have been considered as an efficient way to decrease piglet mortality (Blackshaw, 1994; Marchant et al., 2000). However, there are some studies showing that overall piglet mortality does not have to necessarily differ in crates and loose-housing systems (e.g. Weber et al., 2007; 2009; Pedersen et al., 2011; Kilbride et al., 2012; Melišová et al., 2012). Similarly, Wechsler and Weber (2007) in their review concluded that, taking scientific evidence as well as practical experience into account, piglet mortality in loose farrowing systems need not exceed that of crate system. Some countries in Europe have already banned housing of lactating sows in farrowing crates in their legislation (Norway, Sweden, and Switzerland) some other countries are currently in the process of its limitation (Austria). In organic farming, keeping of lactating sows in the farrowing cages is not compatible with European Union legislation. Therefore, in order to increase the number of countries in which sows would be kept in loose housing systems, such housing systems must ensure farmers of low piglet mortality in order to be economically profitable and competitive with crated farrowing systems.

1.2. Management routines at the time of farrowing

Under semi-natural conditions, a domestic sow will separate herself from the social group and seek a suitable nest site 1 – 2 days prior to farrowing (e.g. Jensen, 1988). When a suitable nest site has been located, she excavates a hollow and collects suitable material to build a nest in it, spending typically 5 – 10 h on the construction (e.g. Wood-Gush and Stolba, 1982; Jensen et al., 1993). The nest contain enough material to cover the piglets completely, and in some cases the sow as well (Jensen et al., 1989). During the first two days after birth, the sow will spend 90% of her time in the nest, only leaving the nest for brief foraging trips (Stangel and Jensen, 1991). The piglets spend these first days after birth resting in close contact with the sow and littermates, leaving the nest only to defecate (Stangel and Jensen, 1991). Remaining in the nest after birth serves several adaptive functions for the piglets: it facilitates the development of the mother-young bond (Jensen and Redbo, 1987), it reduces the chance of becoming separated from the sow or being detected by predators, and perhaps more importantly, gaining warmth (Fiala and Hurnik, 1983) and food from the udder. As other altricial mammals, piglets are born without fur or brown adipose tissue so their thermoregulatory capacity is poorly developed during the first days after birth (e.g. Berthon et al., 1994; Herpin et al., 2002). Although hypothermia is rarely recorded as cause of death in commercial pig herds, it might often be the primary cause of starvation and crushing (reviewed by Edwards, 2002), as hypothermia renders the piglet less able to find a teat or avoid overlying by the sow (English, 1993). Heat from the udder will reduce the amount of energy needed to maintain body temperature and the intake of colostrum provides a valuable energy source for thermoregulation (Herpin et al., 1994), which in turn may increase the piglets' chances of survival.

Temperatures in the commercial farrowing unit are normally kept within sow's thermal comfort zone (around 20 °C) but it is below the piglets' lower critical temperature (34 °C), which can induce cold stress and render the piglets less viable (e.g. English, 1993). Heat loss is especially critical for piglets directly after birth, as they are wet with birth fluids. Newborn piglets can lose more than 2 °C in body temperature from birth until they find a teat or enter the heated creep area, and this heat loss may be fatal for weak and small piglets, as they are in greater risk of starvation or being crushed by the sow (Baxter et al., 2008; Pedersen et al., 2011). Colostrum intake is vital in order to improve thermoregulation and survival in newborn piglets, as body temperature and heat production are positively related to colostrum intake (e.g. Gentz et al., 1970), and piglets without colostrum intake are unable to reach thermostability (Noblet and Le Dividich, 1981). In addition, hungry piglets often stay close to the sows' udder, which may further increase the risk of crushing (Weary et al., 1996). Previous studies found that piglets who survive to weaning are generally heavier, born earlier in the litter and spend less time from birth to first suckling (Hartsock and Graves, 1976; Tuchscherer et al., 2000; Baxter et al., 2008). Knowing that it can take up to 3 hours for a piglet to reach a teat after birth (e.g. Thingnes et al., 2008), it is important to reduce the heat loss after birth, and subsequently, perhaps reduce the time from birth to colostrum intake. In order to reduce piglet heat loss, the farrowing pen is often equipped with a suitable microclimate (34 – 36 °C) for the piglets. Previous studies found several management routines that reduced piglet mortality, including supervising the farrowings and provision of oxygen, giving milk and fluids orally or tying the umbilical cord (e.g. Holyoake et al., 1995; White et al., 1996; Alonso-Spilsbury et al., 2007). An efficient and simple way of reducing the heat loss after birth is to dry the piglets and place them underneath the heat lamp, which alone can reduce piglet mortality by 6 – 8 % (McGinnis et al., 1981; Christison et al., 1997; Andersen et al., 2009). However, Christison et al. (1997) did not find a relationship between drying piglets, placing them in the creep area, and time to first suckle. Comparatively, helping piglets to get colostrum after birth by placing them near the udder has improved piglet survival in commercial loose-housed sow herds (Andersen et al., 2007). For the pig farmer, it is important to know which of these routines are the most efficient with regards to reducing postnatal mortality, and thus being able to wean more piglets. To develop some rules of thumb on management around the time of farrowing would benefit pig welfare and survival, thus improve the farmer's economic return, as long as the routines are simple and not too time-consuming.

1.3. Piglets' use of the creep area

Piglets in semi-natural conditions start following the sow on small foraging trips from 4 days after birth, and the sow and litter rejoin the group around 10 days after farrowing (Newberry and Wood-Gush, 1988; Jensen, 1988). Unlike the sow–piglet interactions observed in semi-natural conditions, where the sow leaves the piglets in the nest, modern farrowing systems are based on the principle that newborn piglets will leave the sow area where the temperature is kept within sow's thermal comfort zone 20 °C and enter previously mentioned much warmer heated creep area (34 – 36 °C). However, numerous studies have found that young piglets prefer to huddle near the sow and littermates despite unfavourable thermal conditions in the sow area, instead of staying in the creep area during the first days after birth (e.g. Hrupka et al., 1998; Andersen et al., 2007; Vasdal et al., 2009). In fact, Hrupka et al. (2000) found that piglets were more attracted to an anesthetized piglet in a cold chamber than to an empty warm chamber, suggesting that the attraction to physical contact is stronger than the attraction to ambient heat. The piglets only start using the creep area to a substantial extent from day 3 after birth (e.g. Hrupka et al., 1998; Berg et al., 2006; Vasdal et al., 2009), which is the age when they would naturally start exploring the nest surroundings together with the sow (e.g. Stangel and Jensen, 1991). Despite the piglets' motivation to lie close to the sow, many farmers' constructions and scientific studies have been aimed at increasing the attractiveness of the creep area while the use of the creep area in farrowing crates has been increased by: reducing temperature in the sow area (Zhou and Xin, 1999; Schormann and Hoy, 2006; Burri et al., 2009), adding a warm water bed in the creep area (Ziron and Hoy, 2003) or providing a simulated udder in the creep area (Lay et al., 1999;

Toscano and Lay, 2005). Piglets in farrowing crates spend more time in the creep area than piglets in farrowing pens, possibly because the sow area is made less attractive by slatted floors, horizontal bars around the sow and reduced space (Blackshaw et al., 1994; Vasdal et al., 2009). Another reason for this difference might be the extra attraction of the sow area to piglets resulting from higher maternal motivation displayed by sows in farrowing pens showing more piglet-directed behaviour, higher responsiveness to piglet screams and increased nursing behaviour (e.g. Cronin et al., 1996; Arey and Sancha, 1996; Jarvis et al., 2005). Vasdal et al. (2010) found that 24-h-old piglets preferred 42 °C to other, lower infrared temperatures, and a thick layer of sawdust to both a foam mattress and a water mattress. Thus, it might be possible to increase the use of the creep area in loose-housed sows by combining a thick layer of sawdust with high infrared temperatures. However, although previous studies have shown that piglets in farrowing crates spend more time in the creep area than piglets in farrowing pens, a relationship between increased time spent in the creep area and piglet mortality has not yet been documented. This information would be important to the ongoing work of reducing piglet mortality in loose-housed sows.

1.4. Sow pre-lying communication with piglets

Besides management routines conducted straight after the farrowing and attraction of piglets into the nest area in order to avoid piglet crushing by the sow, behaviour of the mother might also affect piglet crushing and mortality. Several studies made in loose-housing systems allowing the sow to move around and communicate freely with her piglets show that maternal motivation and protectiveness have a large impact on piglet survival (Wechsler and Hegglin, 1997; Špinka et al., 2000; Marchant et al., 2001; Pitts et al., 2002; Andersen et al., 2005). Before lying down, sows perform specific types of pre-lying behaviour (e.g. Clough and Baxter, 1984; Blackshaw and Hagelso, 1990; Wischner et al., 2010) which might be functional by attracting piglets' attention and giving them enough time to move (e.g. Marchant et al., 1996). These types of behaviour are: rooting (Blackshaw and Hagelso, 1990; Špinka et al., 2000; Marchant et al., 2001; Valros et al., 2003; Pokorná et al., 2008; Burri et al., 2009; Wischner et al., 2010), pawing (Marchant et al., 2001; Pokorná et al., 2008; Wischner et al., 2010), sniffing piglets (Valros et al., 2003; Pokorná et al., 2008; Wischner et al., 2010), nudging piglets (Marchant et al., 2001), looking around (Marchant et al., 2001; Wischner et al., 2010), turning around (Burri et al., 2009) and descending vertically (Špinka et al., 2000). In a group farrowing system, increased incidence of sow's pre-lying behaviour decreased the occurrence of dangerous situations leading to crushing (Marchant et al., 2001). In crates, sows that have not crushed piglets perform pre-lying behaviour more often than sows that crush at least one piglet (Wischner et al., 2010). In contrast to this, some studies focusing on different pre-lying behaviours both in crated and loose-housed sows, did not find any relationship between pre-lying behaviour and probability of crushing (Pokorná et al., 2008), the incidence of near-crushing situations (Burri et al., 2009) or piglet mortality in general (Špinka et al., 2000). Valros et al. (2003) found lower piglet mortality due to crushing in indoor, loose-housed sows with increasing rooting activity, but sniffing piglets and other pre-lying behaviour was not significantly related to the incidence of crushing. According to Johnson et al. (2007), sows kept outdoors that did not crush any piglets spent more time pawing than sows that crushed some of their piglets. However, this was not the case for rooting behaviour with the snout directed towards the ground in a similar study with outdoor sows (Špinka et al., 2000). It is likely that communication through sniffing, nudging and vocalization have a larger impact on piglet location and the chances of getting crushed than the less focused rooting or the nature of posture changes. These contradictory results question the function of these two behaviours as preparatory movements for lying down. Except for nest building, pawing is most commonly observed in relation to lying down movements (e.g. Johnson et al., 2007), whereas motivation for rooting is also high in pregnant sows and can be observed in a wide range of situations (e.g. Studnitz et al., 2007). Sows that do not crush any of their piglets respond sooner to piglet distress calls and sniff their piglets more than sows that crush several piglets (Andersen et al., 2005). Although there are several studies on vocal communication during nursing (e.g. Algers and Jensen, 1985; Blackshaw et al., 1996; Špinka et al., 2002) and offspring recognition (e.g. Illmann et al., 2002), vocal communication between sow and piglets, specifically before the sow lies down has, to our knowledge, not been documented. The relationship between different pre-lying behaviours and the incidence of crushing events still needs to be systematically studied.

2. Scientific hypothesis and objectives

The main aim of this thesis was to investigate the effect of different management routines at the time of farrowing (Paper I), provision of optimal creep area for piglets (Paper II) and maternal behaviour of the sow before lying down (Paper III) on piglet behaviour and piglet mortality.

2.1. Paper I: Management routines at the time of farrowing

We studied the effects of six different management routines at the time of farrowing on piglets' latency to first suckle, heat loss, weight gain and postnatal piglet mortality. We tested the following hypothesis:

H1: The combination of the treatments (placing piglets at the udder + drying and placing piglets in the creep area + drying) will decrease piglets' latency to first suckle after the birth, decrease heat loss, increase weight gain and decrease piglet mortality compared to the other four treatments (control, drying alone, placing at the udder alone, placing in the creep area alone).

2.2. Paper II: Piglets' use of the creep area

We investigated the effect of the thermal comfort and softness of the creep area on time spent by piglets in the creep area during first 3 days pp and how this time affects early piglet mortality. The following hypotheses were tested:

- **H1**: Piglets will spend more time in the creep area with better thermal comfort and softness compared to control treatment.
- **H2:** With more time which piglets spend in the creep area there will be lower proportion of piglet crushing and piglet mortality.

2.3. Paper III: Sow pre-lying communication with piglets

We focused on the impact of sow-piglet communication during the pre-lying behaviour on piglet location and mortality before lying down on Day 0 and Day 2 pp. Also the ontogeny of sow-piglet communication was investigated. We tested the following hypotheses:

- **H1**: With more sows' communication with their piglets there will be fewer piglets present in the specified danger zone (area within one piglet length of the sow on the side on which she is about to lie down).
- **H2**: With more sows' communication with their piglets there will be lower proportion of piglets crushed.
- **H3**: With higher proportion of piglets present in the danger zone there will be higher probability of piglet crushing.
- **H4**: There will be higher sow-piglet communication on Day 0 pp compared to Day 2 pp.

3. Material and methods

3.1. Animals and housing

The data on management routines at the time of farrowing (Paper I) were collected on a commercial Norwegian pig farm with loose-housed sows in 2009. The experiments focusing on attractiveness of different creep areas for piglets (Paper II) and sow pre-lying communication with piglets (Paper III) were conducted at the Pig Research Unit at the Norwegian University of Life Sciences (UMB) with loose housing systems for farrowing sows in 2009. The experimental subjects were 67 (Paper I), 46 (Paper II) and 18 (Paper III) healthy Yorkshire x Norwegian Landrace inseminated with semen from Duroc x Landrace boar and their piglets. Sow parities ranged from 1 to 7 (2.7 ± 0.2, Paper I and 2.5 ± 1.8, Paper III) and from 1 to 8 (2.7 ± 0.2, Paper II). The sows were moved from the group housing gestation unit to the farrowing unit at the day 110 post-insemination. They were housed in individual loose-housed farrowing unit measuring 6.2 m^2 (Paper I) and 8.9 m^2 (Paper II, III). Part of the pen accessible to the sow measured 5.0 m^2 (Paper I) and 7.0 m^2 (Paper II, III). The farrowing units were insulated and mechanically ventilated and the air temperature was kept at 20 ºC until farrowing, than reduced to 16 ºC the day after the farrowing. There was a 2 cm layer of sawdust on the solid floor in the sow area (Paper I, II and III) and creep area (Paper I and III) which was changed on daily basis. The creep areas were heated by floor heat providing surface temperature 28 ºC (Paper I) and by red infrared heat lamp providing 30 ºC (Paper III). In Paper II the creep areas were maintained according to the treatment requirements (see below). There was no human assistance provided to a piglet when it was crushed. However, to follow common practices of commercial pig farming and to avoid suffering the ethical decision was taken to humanely euthanize the piglets which were not able to survive (body deformations, injuries etc.). All dead piglets were subjected to a post-mortem examination to determine cause of death.

3.2. Experimental design and behavioural observations

Data for Paper I were collected via direct observations, behavioural observations for Paper II and III were analyzed from video-recordings 3 days pp.

3.2.1. Paper I: Management routines at the time of farrowing

For all piglets in the experiment was registered: i) Initial registrations: birth weight, rectal temperature at birth and latency from birth to first suckle, ii) 2 hour registrations: weight at 2 hours after birth and rectal temperature 2 hours after birth, iii) 24 hour registrations: weight at 24 hours after birth and rectal temperature at 24 hours after birth.

In addition to the registrations mentioned above, one of the following six treatments which was allotted randomly was conducted on the whole litter directly after the initial registrations: control (CON, n = 14) no treatment; (CREEP, n = 13) piglets placed in the creep area; (UDDER n = 10), piglets placed at the udder; (DRY, n = 10) piglets dried and placed back where found; (DRYCREEP n = 9) piglets dried and placed in creep area and (DRYUDD n = 11) piglets dried and placed at the udder. After the 2 hour and the 24 hour registrations, the piglet was placed back where it was found at the time. Registrations on each sow included parity and number of functional teats, and the number of functional teats per piglet in each litter was then calculated.

3.2.2. Paper II: Piglets' use of the creep area

In order to score the location of the piglets, the farrowing pen was divided into two zones: the creep area and the sow area (the rest of the pen) and number of piglets in each zone were counted. Piglet location in the pen was scored using instantaneous sampling every 10 min from 08:00 h to 14:00 h (6 h) and from 20:00 h to 02:00 h (6 h) at Day 0 (0 – 24 h), Day 1 (25 – 48 h) and Day 2 (49 – 72 h), adding up to a total of 216 observations per litter. These two periods were chosen due to the presumed high activity at 08:00 – 14:00 hours, and presumed low activity at 20:00 – 02:00 h.

The different creep areas treatments during the first three days pp (0 – 72 h) were following: Control (CON); concrete floor in the creep area with < 100 g of sawdust (a similar amount to that used in commercial herds), bedding (BED); an insulated and soft bedding in the creep area with thick layer of sawdust (7 – 10 cm) and HUT; an insulated and soft bedding in the creep area as in BED, in addition to an extra wall, to increase the heat conserving capacity in the creep area. During farrowing batches, a total of 46 sows were randomly allotted to one of the treatment pens: CON (n = 17), BED (n = 15) and HUT (n = 14) six days before expected farrowing. The infrared temperature was in CON and BED 30 °C, in HUT was around 2 °C higher.

3.2.3. Paper III: Sow pre-lying communication with piglets

Sow pre-lying communication was analyzed during 10 standing-to-lying events per sow without external disturbance on Day 0 (from the end of farrowing until 24 h pp) and Day 2 (49 – 72 h pp). We defined sow pre-lying communication as a sum of the frequency of sow vocalization, the frequency of sniffing (sow's snout is at the distance of less than 10 cm from the body of the piglet) and the frequency of nudging (physical contact of sow's snout with piglet) which was counted 2 min before a sow began to lie down.

At the moment the sow began to lift a front foot and placed her knee on the floor, the number of piglets present in the danger zone (area within one piglet length of the sow on which she is about to lie down) were counted. The proportion of piglets which were present in the danger zone was calculated as the percentage of piglets in the litter. The behavioural analyses were conducted on the Observer software (The Observer, Version 8, Noldus Information Technology, Netherlands).

4. Statistical analysis

Data for Paper I – III were analysed using the SAS software (version 9.2.).

In Paper I the difference between treatments with respect to latency to suckle, weight gain and heat loss were analyzed using a generalized linear model, Glimmix procedure (with Poisson distribution) including both fixed and random effects and with individual piglets as the statistical unit. Postnatal piglet mortality (with Poisson distribution) was analyzed using a generalized linear model (Genmod procedure). The model included the following fixed effects: treatment (1 – 6), batch (1, 2, 3), sow parity category (1, 2, 3), and the interactions between treatment and batch and between treatment and number of functional teats per piglet were included in the model. Sow was included as a random effect, and birth weight and teats per piglet was included as continuous variables in the model.

In Paper II the litter was used as the statistical unit. The differences in piglet behaviour and location between treatments and days were analyzed using a Glimmix model procedure with Poisson distribution, including the following class variables: treatment (CON, BED, HUT), batch (1, 2, 3 and 4), days after farrowing (0, 1, 2) and sow parity (1 – 8). The interactions between treatment × batch and treatment × day were also included in the model. Sow was included as a random effect, and litter size was included as a continuous variable in the model. Piglet mortality was analyzed using a Genmod procedure in SAS with Poisson distribution including the following class variables and their interactions: treatment (CON, BED, HUT), batch (1, 2, 3, 4), days after farrowing (0, 1, 2) and sow parity (1 – 8), with litter size and birth weight included as a continuous variable. Due to the lack of normal distribution, relationships between piglet location and piglet mortality were analyzed by a Spearman Rank correlation analysis.

In Paper III for all statistical analysis, the individual sow was considered as an independent subject. The predictors of time period, parity and litter size were covariates in all models. The predictor time period was a categorical variable with two levels (Day 0 and Day 2); the predictors parity and litter size were included in the model as continuous variables. Negative binomial regression (procedure Genmod) was applied to test the effects of sow–piglet communication on the proportion of piglets present in the danger zone with predictors sniffing, sow vocalization, and nudging. The logistic regression (procedure Genmod) was applied to test the effect of each component of sow per-lying communication separately for Day 0 and Day 2 on the probability of crushing. Similarly, logistic regression was applied (procedure Genmod) to test separately the effects of proportion of piglets in the danger zone for each time period on probability of piglet crushing. The Poisson regression model was applied (procedure Genmod) to assess whether the frequency of sow vocalization, sniffing, nudging and sow pre-lying communication in total differed between Day 0 and Day 2.

5. Results

5.1. Paper I: Management at the time of farrowing

The latency from birth to first suckle (average: 62 ± 1.9, range: 1 – 496 min) was shortest in DRYUDD treatment, followed by UDDER ($F_{5,694}$ = 5.8, P < 0.001). The latency to first suckle was also shorter when there were fewer piglets per teat ($\chi^2_{1,39}$ = 23.2, P < 0.01), in piglets with higher birth weight ($F_{1,694}$ = 18.2, P < 0.001), a higher weight at 2 hours ($F_{1,694}$ = 17.4, P < 0.001), and in piglets with higher rectal temperature at 2 hours after birth ($F_{1.694}$ = 8.1, P < 0.01). Increased litter size tended to increase latency to first suckle ($F_{1,694}$ = 6.9, P < 0.1).

Piglets in CREEP had a lower heat loss from birth until 2 hours compared to the other treatments ($F_{5,716}$ = 6.5, P < 0.01), but there was no effect of treatment on heat loss from birth until 24 hours. Heat loss until 2 hours after birth was smaller in heavier piglets ($\chi^2_{1,39}$ = 59.1, P < 0.001), and in piglets with shorter latency to suckle ($\chi^2_{1,39}$ = 11.2, P < 0.01).

Piglets in CREEP had the lowest weight gain from birth to 2 hours ($F_{5,728}$ = 3.2, P < 0.01), while at 24 hours, the piglets in CREEP, UDDER and DRY had a lower weight gain compared to the other treatments ($F_{5,728}$ = 8.9, P < 0.001).

Postnatal mortality (% of litter size) until weaning was on average 10.1 ± 1.4 %. More live-born piglets died in UDDER treatment compared to CON and DRYCREEP ($\chi^2_{5,39}$ = 75.2, P < 0.001), but there were no other significant differences in postnatal mortality between treatments. When merging all six treatments into three classes, (1) Control, (2) NoDry (CREEP+UDDER) and (3) Dried (DRY+DRYCREEP+DRYUDD), there were higher postnatal mortality in NoDry (11.5 ± 2.1, 15.1 ± 3.8) compared to Control (7.9 ± 2.1) and Dried (9.7 ± 2.7, 7.1 ± 2.7, 9.3 ± 3.5 respectively; $\chi^2_{2,29}$ = 32.1, P < 0.001). Postnatal mortality was lower when there were fewer piglets per teat in a litter ($\chi^2_{1,39}$ = 27.6, P < 0.001). Higher birth weight ($\chi^2_{1,39}$ = 29.1, P < 0.001), a shorter latency from birth to first suckle ($\chi^2_{1,39}$ = 8.0, P < 0.01), and a higher rectal temperature at 2 hours after birth ($\chi^2_{1,39}$ = 12.4, P < 0.001) were all associated with a lower piglet mortality. An increased litter size resulted in an overall higher postnatal mortality ($\chi^2_{1,39}$ = 48.4, P < 0.001).

5.2. Paper II: Piglets' use of the creep area

Piglets in the HUT treatment (17.0 ± 5.0) spent less time (% of observations) in the creep area than piglets in the CON (28.8 ± 4.5) and BED (30.4 ± 4.7) treatments ($F_{2.88}$ = 10.8, P < 0.001), while there was no difference in time spent (% of observations) in the creep area between the CON and BED treatment. The number of piglets in the creep area increased in the first two days after farrowing ($F_{4.88}$ = 6.8; P < 0.01), and this increase was highest in the BED treatment ($F_{4.88}$ = 2.7; P < 0.05).

There were no significant differences in piglet mortality among the three treatments (CON: 13.4 ± 3.9; BED: 12.9 ± 3.2; HUT: 15.2 ± 3.3), nor in the percentage of piglets being crushed by the sow (CON: 5.2 ± 2.6; BED: 9.2 ± 2.9; HUT: 8.2 ± 3.5). The total time spent (% of obs.) in the creep area was not significantly related to piglet mortality in any of the treatments on Day 0, Day 1 or Day 2.

5.3. Paper III: Sow pre-lying communication with piglets

The proportion of piglets present in the danger zone increased significantly with increased frequency of vocalization (P < 0.05) and sniffing (P < 0.05); nudging did not have any effect. On Day 0, there was a higher proportion of piglets present in the danger zone than on Day 2 (P < 0.01, 15.5 % piglets on Day 0 vs. 5.8 % piglets on Day 2).

Over the three days post-partum, 14.4 % of piglets (34 out of 236 live born piglets) died, 6.4 % of piglets died as a result of crushing. The probability of piglet crushing was not significantly affected by any component of the sow pre-lying communication (vocalization: P = 0.67, $\chi^2_{(1)}$ = 0.18 on Day 0 and P = 0.45, $\chi^2_{(1)}$ = 0.57 on Day 2; sniffing: P = 0.11, $\chi^2_{(1)}$ = 2.55 on Day 0 and P = 0.11, $\chi^2_{(1)}$ = 2.5 on Day 2; nudging: P = 0.21, $\chi^2_{(1)}$ = 1.61 on Day 0 and P = 0.3, $\chi^2_{(1)}$ = 1.08 on Day 2) nor by proportion of piglets in the danger zone (P = 0.27, $\chi^2_{(1)}$ = 1.2). On Day 0 compared to Day 2 there was a higher number of pre-lying communication in total (Z = 3.41, P < 0.0001), a higher frequency of sow vocalization (Z = 4.17, P < 0.0001) and nudging tended to increase (Z = 1.88, P < 0.1). Sniffing was not effected by the time period (Z = − 0.14).

6. Discussion

The results from Paper I illustrate how complex the issue of piglet mortality is as specific management treatments can help to reduce piglet mortality but there are several piglet-related factors which also effect strongly piglet mortality. The experiments conducted in Paper II and III allowed us to better understand substantial piglet need of sow's proximity within first few days after the farrowing which is in a contrast to common beliefs and farming practices on commercial pig farms.

6.1. Paper I: Management at the time of farrowing

We were not able to confirm that treatments drying piglets and placing them at the udder or creep area would clearly increase latency to first suckle and weight gain and decrease heat loss and piglet mortality compared to the rest of the treatments. Nevertheless, the three treatments that included drying the piglets all had postnatal mortality below 10%, supporting previous findings that reduced heat loss after birth is one of the key factors for early piglet survival (Baxter et al., 2008; Pedersen et al., 2011). However, contrary to earlier findings (McGinnis et al., 1981; Christison et al., 1997; Andersen et al., 2009), there were no clear differences in postnatal mortality between the control treatment and the three dried treatments. The control treatment in the present study was handled in order to compare the weight gain and temperature development, and this stimulation was perhaps enough to increase piglet viability and reduce potential differences between treatments.

The highest postnatal mortality was found in litters that were placed at the udder without being dried first. Although the control piglets were not dried either, the litter size in the control treatment was on average 1.5 piglets less per litter compared to the later. Placing piglets in the creep area without drying them first, had clear negative effects on latency to suckle and weight gain, both of which is important for piglet survival. However, the mortality was still lowest in the DRY and DRYCREEP treatments compared to the other treatments, but not the control treatment. This is contrast to Andersen et al. (2009) who documented much lower mortality when piglets were either placed directly in the creep area immediately after birth or both dried and placed under the heat lamp compared to control litters. The less clear effects of the treatments in the present study may be explained by the suboptimal design of the creep area and the exceptionally high litter sizes in some of the treatments. The sows were observed resting towards the entrance of the creep area and thus blocking the piglets from getting to the udder. If we look at all results together and the results from other studies (Andersen et al., 2007, 2009), we may still conclude that routines to reduce heat loss such as drying and helping the piglets to the udder or placing them under the heat lamp would be beneficial for survival provided that the piglets have free access to the creep area. In the DRYUDD treatment the mean litter size was almost 15, but nonetheless mortality was below 10%, which is remarkably low.

6.2. Paper II: Piglets' use of the creep area

We did not confirm any of our two hypotheses as improving the thermal comfort and softness in the creep area neither increased the use of the creep area, nor was there any relationship between use of the creep area and piglet crushing or mortality. The creep area has long been considered an important part of the farrowing environment, providing the piglets with a suitable microclimate and physical protection from the sow, however, it appears difficult to attract newborn piglets away from the sow. The hut was actually least used of the three creep areas, opposite to what was predicted based on previous findings; that piglets are attracted to warm and soft areas when the sow is crated (e.g. Zhou and Xin, 1999; Schormann and Hoy, 2006; Burri et al., 2009) and in piglet preference tests (e.g. Hrupka et al., 2000; Vasdal et al., 2010). In total, the piglets in the present study spent less than a third of their time in the creep area, thus none of the three creep area treatments were able to attract the piglets away from the sow to a greater extent than reported in other studies of loose-housed sows (e.g. Berg et al., 2006; Vasdal et al., 2009). This can be explained by the fact that piglets are strongly motivated to lie close to the sow and litter mates early after birth regardless of the presence of a heated creep area (Hrupka et al., 1998; Andersen et al., 2007). Lying close to the sow after birth is a highly adaptive behaviour as staying close to the udder increases the piglets' chance of survival, and it can therefore be considered as a battle against biology to aim at attracting newborn piglets away from the sow.

In accordance with previous findings (e.g. Berg et al., 2006), there were large differences between litters in use of the creep area. However, there was no relationship between time spent in the creep area and piglet mortality. If increased use of the creep area was positive for piglet survival, differences in mortality should be expected between litters with high and low use of creep area. Vasdal et al. (2009) found that piglets in crates spent significantly more time in the creep area than piglets in pens, however, there were no differences in mortality between these environments (Pedersen et al., 2011). These results suggest that the creep area is less important for piglet survival than previously thought. Contrary to previous studies (e.g. Weary et al., 1996), there was no relationship between times spent resting near the sow and piglet mortality in the present study. Thus it might be other factors, such as the physical state of the piglet like birth weight and body temperature (e.g. Pedersen et al., 2011) that explains early piglet mortality.

6.3. Paper III: Sow pre-lying communication

Contrary to our predictions, more communication initiated by the sow (i.e. vocalization, sniffing) was associated with a higher proportion of piglets in the danger zone before lying down and, there was no effect of sow–piglet communication on the incidence of piglets being crushed, nor the proportion of piglets in danger zone effected piglet crushing. We confirmed that there was a higher pre-lying communication on the day of the farrowing (Day 0) compared to Day 2 pp.

It has been suggested that sow pre-lying behaviour may help to reduce the risk of crushing by ensuring that piglets are awake and able to anticipate the forthcoming lying down event (Damm et al., 2005), and move out of the danger zone (Blackshaw and Hagelso, 1990; Marchant et al., 2001). However, most of the cited studies focused on the pre-lying behaviour and the probability of crushing but did not study the relationship between pre-lying behaviour and piglet location. Our results indicate that more sow pre-lying communication attracted a higher proportion of the piglets close to the sow in the place with a higher risk of crushing (Blackshaw and Hagelso, 1990; Marchant et al., 2001). Staying near the sow seems to be an adaptive behaviour of the piglets because the sow provides warmth, milk and protection (in outdoor environments) and they are also sorting out their teat order and teat fidelity (De Passillé et al., 1988). Therefore, the area in very close proximity to the sow (i.e. the danger zone) might be perceived by neonatal piglets as the optimal place in the pen. The result is not a new observation as mentioned above; in semi-natural conditions piglets spend the first few days after birth in the nest in close contact with the sow (Jensen, 1986; Stangel and Jensen, 1991). This knowledge relating to the natural behaviour of newborn piglets, known for almost 20 years, has not been implemented as design criteria for farrowing pens.

Similar to other studies which looked at the effect of different components of the pre-lying behaviour and piglet mortality (Špinka et al., 2000; Pokorná et al., 2008), we did not detect any association between the pre-lying communication and piglet crushing. In contrast, standing-to-lying events ending by piglet crushing were more frequent when sows performed none or very little pre-lying behaviour (Marchant et al., 2001), and performed less rooting on Day 3 (Valros et al., 2003). These contradictory results might be due to slightly different approaches and methods used.

How dangerous is piglet presence in the danger zone? Apparently, there is a trade-off between the costs and benefits which the closeness of the mother represents for piglets. 0ur results showed that there was no effect of the proportion of piglets in the danger zone on piglet crushing. When a piglet gets trapped it starts screaming immediately. Weary et al. (1996) showed that piglets which are trapped under the sow for less than 1 min generally survive. Thus, staying close to the mother within the first few days post partum might increase the risk of maternal crushing (Weary et al., 1996; Marchant et al., 2001) but crushing may not be fatal (in our study on Day 0, the number of events when fatal crushing occurred during lying was more than 4.5 times lower than the number of events when at least one piglet was present in the danger zone) and the benefits might be greater than the risks.

The frequency of pre-lying communication (sow pre-lying communication in total, vocalization and nudging) was higher on Day 0 compared to Day 2 when the piglets are most vulnerable and the risk of crushing is greatest (Weary et al., 1996; Marchant et al., 2001). The same ontogeny effect was found by Marchant et al. (2001) and Blackshaw and Hagelso (1990) for different components of pre-lying behaviour. However, sniffing and sow vocalization do not exclusively occur before lying down but they have been observed during and after birth of piglets and before and after nursing (Whatson and Bertram, 1982 – 1983; Jensen, 1988; Jarvis et al., 1999; Illmann et al., 2001; Pedersen et al., 2003). Another function of sow pre-lying communication might be solely to support development of the olfactory (Maletínská et al., 2002) as well as acoustical mother–young bond which plays important role in piglet survival. Given the low frequency of nudging behaviour displayed by the sow in this study, it is questionable whether it plays an important role in sow–piglet communication.

6.4. Paper IV: The effect of housing on piglet mortality

Weber et al. (2007) and Kilbride et al. (2012) in their studies based on a large sample size concluded that in loose-housing there is indeed higher probability of piglet crushing, however piglet mortality caused by other reasons than by crushing (starvation, sickness etc.) is, on the contrary, higher in crated systems. The explanation for it is that there are a number of important factors that determine piglet mortality. Piglets with low birth weight are more prone to piglet crushing (e.g. Pedersen et al., 2011; Melišová et al., 2011) and post-mortem analyzes show that the majority of crushed piglets does not have milk in the stomach (Andersen et al., 2011), which is probably due to their failure in fights for the teats with their siblings. These hungry piglets are probably in loose-housing systems crushed shortly after the farrowing, whereas in crated system die a bit later due to starvation (Weber et al., 2007). There is also large evidence in literature that piglet condition is strongly affected by litter size and with increased litter size piglet mortality increases (Pedersen et al., 2006, Weber et al., 2009, Vasdal et al., 2011; Kilbride et al., 2012). These finding should be taken into account when breeding new traits of farrowing sows.

7. Conclusions and Recommendation for Scientific and Technical Development

In conclusion, regardless of management treatment after birth, several piglet-related factors were found to be highly important for postnatal mortality, such as the number of functional teats per piglet, birth weight, the latency from birth to first suckle, and rectal temperature at 2 hours after birth (Paper I). Drying the piglets after birth and placing them at the udder resulted in reduced latency to suckle in our experiment. Despite having the largest mean litter size of the treatments, less than 10% of the piglets in DRYUDD died, which is a very low number. Piglet mortality increased with increased litter size. These findings should be taken in account on commercial pig farms - the farrowing should be attended by the barn staff that could dry the piglets after birth, inspect and count number of functional teats and help the piglets to get the first milk intake as soon as possible after birth in order to decrease piglet mortality. Cross-fostering (when farrowings are synchronized) should be conducted when litter size exceeds number of functional teats. Furthermore, by reducing selection pressure in breeding sows in order to achieve the highest possible litter size could help to reduce piglet mortality (Paper I and Paper IV).

In contrast, offering a heated creep area with soft bedding does not seem a proper measure in order to decrease piglet mortality as quality of the creep area appears to have little impact on piglet survival. Comfortable bedding did not increase time spent by piglets away from the sow which illustrates strong piglets' need to lie in close nearness to their mother during first days pp (Paper II). Similarly, contrary to our predictions, sow pre-lying communication did not serve for moving piglets out of predefined danger zone but attracted them towards sow's proximity. The important finding from this experiment is that piglet attraction towards the sow was without increase of the incidence of piglet crushing (Paper III). These findings have been implemented into the development of new loose-farrowing pens called UMB pens at the Norwegian University of Life Sciences. These pens do not contain any separated creep area (piglets are located around the sow in her lying area in the pen; heating for piglets is provided by floor heating placed in one corner of sow's lying area) which are currently tested on a larger scale for future commercial use in Norway.

There is increased evidence from literature suggesting competitiveness of loose farrowing systems with crated systems in terms of piglet mortality (Paper IV).

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Management routines at the time of farrowing—effects on teat success and postnatal piglet mortality from loose housed sows

Guro Vasdal [a,*], Ingrid Østensen [a], Michala Melišová [b], Barbora Bozděchová [b], Gudrun Illmann [b], Inger Lise Andersen [a]

[a] Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, P.O. Box 5003, 1432 Ås, Norway
[b] Department of Ethology, Institute of Animal Science, 104 00 Prague-Uhříněves, Czech Republic

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ABSTRACT

The aim of this experiment was to study the effects of six different management routines at the time of farrowing on latency to first suckle, heat loss, weight gain and postnatal mortality. A total of 872 piglets from 67 loose housed sows in a commercial pig unit were subjected to one of six different management routines: control (CON $n=14$), no treatment; (CREEP $n=13$), placed in creep area; (UDDER $n=10$), placed at the udder; (DRY $n=10$), dried and placed back where found; (DRYCREEP $n=9$), dried and placed in creep area; and (DRYUDD $n=11$), dried and placed at the udder. The latency from birth to first suckle, rectal temperature at birth, 2 hours and 24 hours were measured for each piglet, in addition to weight at birth, 2 hours and 24 hours. Latency from birth to first suckle was shortest for piglets in the DRYUDD treatment, followed by the UDDER treatment ($P<0.001$). More live born piglets died in the UDDER treatment compared to the other treatments ($P<0.001$), but there were no other differences between the treatments with regards to postnatal mortality. There was a significant interaction between treatment and batch, with a significantly lower postnatal mortality in the DRYUDD treatment than CON in batch 2, but not in batch 1 and 3 ($P<0.001$). Large litter sizes resulted in a higher postnatal mortality in all treatments ($P<0.001$), and tended to reduce latency to suckle ($P<0.1$). In conclusion, drying the piglets after birth and placing them at the udder resulted in reduced postnatal mortality in batch 2, but not in the other two batches. Despite having the largest mean litter size of the treatments, less than 10% of the piglets in DRYUDD died, which is remarkably low for loose housed sows. Regardless of treatment, several piglet-related factors were found to be highly important for postnatal mortality, such as the number of functional teats per piglet ($P<0.001$), birth weight ($P<0.001$), the latency from birth to first suckle ($P<0.01$), and rectal temperature at 2 hours after birth ($P<0.001$).

1. Introduction

Prenatal factors, maternal behaviour, physical environment and the management around farrowing all play an important role in piglet survival (e.g. Andersen et al., 2005; Baxter et al., 2008; Andersen et al., 2009). Temperatures in the farrowing unit are normally kept below the piglets' lower critical temperature (34 °C), which can induce cold stress and render the piglets less viable (e.g. English, 1993). Heat loss is especially critical for piglets directly after birth, as they are wet with birth fluids, they have no insulating layer of fat or fur, and have a poorly developed thermoregulatory capacity (Herpin et al., 2002). Newborn piglets can lose more than 2 °C in body temperature from birth until they find a teat or enter the heated creep area, and this heat loss may be fatal for weak and small piglets, as they are in greater risk of starvation or being crushed by the sow (Baxter et al., 2008; Pedersen et al., 2008). Colostrum intake is vital in order to improve thermoregulation and survival in newborn piglets, as body

* Corresponding author.
E-mail address: guro.vasdal@umb.no (G. Vasdal).

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temperature and heat production are positively related to colostrum intake (e.g. Gentz et al., 1970), and piglets without colostrum intake are unable to reach thermostability (Noblet and Le Dividich, 1981). In addition, hungry piglets often stay close to the sows' udder, which may further increase the risk of crushing (Weary et al., 1996). Previous studies found that piglets who survive to weaning are generally heavier, born earlier in the litter and spend less time from birth to first suckling (Hartsock and Graves, 1976; Tuchscherer et al., 2000; Baxter et al., 2008). Knowing that it can take up to 3 hours for a piglet to reach a teat after birth (e.g. Thingnes et al., 2008), it is important to reduce the heat loss after birth, and subsequently, perhaps reduce the time from birth to colostrum intake.

In order to reduce piglet heat loss, the farrowing pen is often equipped with a suitable microclimate (34–36 °C) for the piglets. However, it is well known that piglets prefer to remain near the sow and littermates for the first few days after birth (e.g. Andersen et al., 2007; Vasdal et al., 2009), and attempts to increase the use of the creep area by providing attractive stimuli have not been successful (Vasdal et al., 2010). Previous studies found several management routines that reduced piglet mortality, including supervising the farrowings and provision of oxygen, giving milk and fluids orally or tying the umbilical cord (e.g. Holyoake et al., 1995; White et al., 1996; Alonso-Spilsbury et al., 2007). An efficient and simple way of reducing the heat loss after birth is to dry the piglets and place them underneath the heat lamp, which alone can reduce piglet mortality by 6–8% (McGinnis et al., 1981; Christison et al., 1997; Andersen et al., 2009). However, Christison et al. (1997) did not find a relationship between drying piglets, placing them in the creep area, and time to first suckle. Comparatively, helping piglets to get colostrum after birth by placing them near the udder has improved piglet survival in commercial loose-housed sow herds (Andersen et al., 2007). For the pig farmer, it is important to know which of these routines are the most efficient with regards to reducing postnatal mortality, and thus being able to wean more piglets. To develop some rules of thumb on management around the time of farrowing would benefit pig welfare and survival, thus improve the farmer's economic return, as long as the routines are simple and not too time-consuming.

The aim of the present experiment was to study the effects of six different management routines at the time of farrowing on latency to first suckle, heat loss, weight gain and postnatal piglet mortality.

2. Materials and methods

2.1. Experimental design

A total of 872 piglets of sows kept in individual farrowing pens were subjected to one of six different management routines, directly after the birth of each piglet. During three farrowing batches, a total of 67 healthy sows were, prior to farrowing, randomly allotted to one of the following treatments: vontrol (CON $n=14$), no treatment; (CREEP $n=13$), placed in creep area; (UDDER $n=10$), placed at the udder; (DRY $n=10$); dried and placed back where found (DRYCREEP $n=9$); dried and placed in creep area and (DRYUDD $n=11$); dried and placed at the udder. All piglets in the experiment were thus handled by experimental staff in order to obtain the data at birth, 2 hours and 24 hours. All piglets in a litter were subjected to the same treatment, and all treatments were represented in each batch.

2.2. Animals and housing

This experiment was conducted on a commercial Norwegian farm with loose housed sows. The sows were Yorkshire × Norwegian Landrace inseminated with Norwegian Landrace × Duroc boar semen. Sow parities ranged from one to seven (average, 2.7 ± 0.2). The parities were categorized as 1 = parity 1–2 ($n=32$), 2 = parity 3–4 ($n=22$), 3 = parity 4–7 ($n=13$). The sows were moved from the group housing gestation unit to the farrowing unit at day 110 post-insemination. The farrowing unit where the farrowing pens were located was insulated and mechanically ventilated and the air temperature was kept at 20 °C until farrowing, and then reduced to 16 °C the day after farrowing.

The sows were housed in standard Tunby® individual farrowing pens, measuring 6.2 m^2 in total. The sow area measured 5.0 m^2 with 2.7 m^2 slatted plastic floor (Fig. 1). There was a 2-cm layer of sawdust on the solid floor in the sow area and in the creep area at the time of farrowing. The creep area (1.2 m^2) was separated from the sow by a diagonal wall with a gap at the bottom for piglets to enter. The creep area was heated by floor heat, providing a surface temperature around 28 °C. There were no heat lamps in the creep areas. The sows were automatically fed a standard lactation concentrate (5% CF, 20% CP) at 08:00 hours, 14:00 hours and 1800 hours. From day 113 until farrowing the sows got 1 kg of straw in the morning for nest building. Then pens were

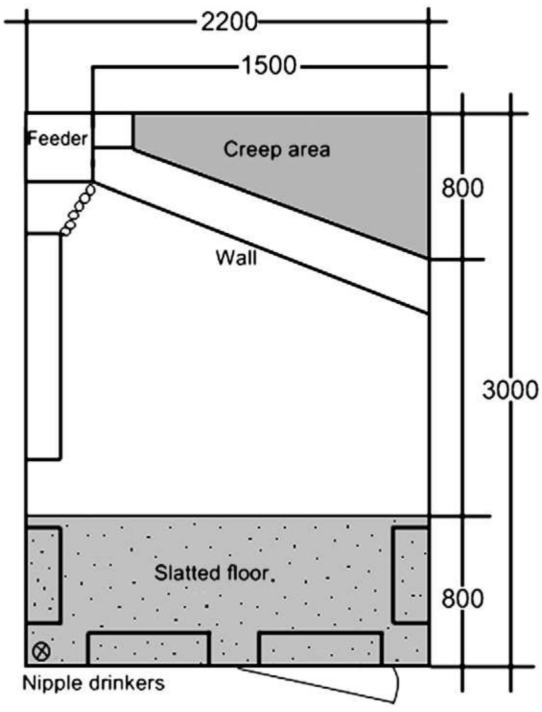

Fig. 1. The farrowing pen. All measures in millimeters. A chain in front of the feeder is part of the pen layout, in order to avoid the sow farrowing in this area.

cleaned out and new sawdust was provided both in the sow area and the creep area twice a day. Wet straw and litter was removed shortly after farrowing and replaced with dry and fresh litter.

Irrespective of treatment, all piglets were tooth ground before 24 hours of age, and male piglets were castrated around day five. To avoid interference with the treatments, no assistance other than the experimental treatments was given to piglets after birth. Piglets in the largest litters were cross-fostered to the smaller litters between 12 and 24 hours after birth, and a total of 58 piglets were cross-fostered during the experiment. Data from the cross-fostered piglets are not included in the results. Piglets were only cross-fostered within treatments. Litter size in this study is thus defined as: no. of liveborn piglets + piglets fostered on – piglets fostered off.

All dead piglets were subjected to a post mortem to determine cause of death, and piglets not able to survive because of injuries or starvation were euthanized by the staff. The dead piglets were categorized as stillborn (lungs sink in water), dead before milk intake (no milk in stomach), dead after milk intake (milk in stomach), crushed before milk intake (physical signs of crushing, no milk in stomach) and crushed after milk intake (physical sign of crushing, milk in stomach). Physical signs of crushing included bruising to the body, cranial bone fractures, haemorrhage or crushed internal organs.

2.3. Experimental procedure

The following parameters were registered for all the piglets in the experiment;

- Initial registrations: Time of birth, birth weight and rectal temperature at birth. All piglets were marked with their birth number.
- Latency from birth to first suckle (three consecutive sucks on a teat).
- 2 hour registrations: weight at 2 hours after birth and rectal temperature 2 hours after birth.
- 24 hour registrations: weight at 24 hours after birth and rectal temperature at 24 hours after birth.

In addition to the registrations mentioned above, one of the following treatments was conducted on the piglet directly after the initial registrations:

- CON: Piglet placed back at birth location
- CREEP: Piglet placed in the creep area
- UDDER: Piglet placed at an available spot at the udder
- DRY: Piglet was dried with straw and paper towel for 15 seconds and placed back where it was found
- DRYCREEP: Piglet was dried with straw and paper towel for 15 seconds and placed in the creep area
- DRYUDD: Piglet was dried with straw and paper towel for 15 seconds and placed at an available spot at the udder

After the 2 hour and the 24 hour registrations, the piglet was placed back where it was found at the time. Registrations on each sow included parity and number of functional teats, and the number of functional teats per piglet in each litter was then calculated.

2.4. Statistical methods

The difference between treatments with respect to latency to suckle, weight gain and heat loss were analyzed using a generalized linear model, GLIMMIX procedure (with Poisson distribution) in SAS including both fixed and random effects, and with individual piglets as the statistical unit. The model included the following fixed effects: treatment (1–6), batch (1, 2, 3), sow parity category (1, 2, 3), and the interactions between treatment and batch and between treatment and number of functional teats per piglet were included in the model. Sow was included as a random effect, and birth weight, birth order and teats per piglet was included as continuous variables in the model. Postnatal piglet mortality (with Poisson distribution) and causes of mortality (with Gamma distribution) were analyzed using a generalized linear model, GENMOD procedure in SAS only including fixed effects, and with mean value per litter as statistical unit. This model included the following fixed effects variables: treatment (1–6), batch (1, 2, 3) and sow parity category (1, 2, 3). The interactions between treatment and batch and between treatment and teats per piglet were also included in the model. Birth weight, latency to suckle, rectal temperature at 2 hours and number of functional teats per piglet were included as continuous variables. Differences in litter size, birth weight and farrowing duration between treatments were analyzed using a GLM procedure in SAS with mean value per litter as statistical unit. This model included the following class variables: treatment (1–6), batch (1, 2, 3) and sow parity (1–7). LSmeans were used to analyse differences between means. Only significant results are presented in the Results section.

3. Results

Litters in DRYUDD treatment had, on average, a larger litter size compared to litters in DRYCREEP and CON treatments ($F_{5.23} = 21.2$, $P < 0.05$; Table 1). The average number of functional teats per sow was 15.0 ± 0.1 (range 13–17). Batch 1 had a higher litter size compared to batch 3 (batch 1, 14.7 ± 0.5; batch 2, 14.3 ± 0.4; batch 3, 13.0 ± 0.3, $F_{2,23} = 3.9$, $P < 0.05$).

3.1. Postnatal piglet mortality

Postnatal mortality (% of litter size) until weaning in this experiment was on average 10.1 ± 1.4%, while the percentage of stillborn piglets was on average 5.9 ± 1.0 (% of total born). More liveborn piglets died in UDDER treatment compared to CON and DRYCREEP ($\chi^2_{5,39} = 75.2$, $P < 0.001$), but there were no other significant differences in postnatal mortality between treatments (Table 1). There was a significant interaction between treatment and batch, with a significantly lower postnatal mortality in the DRYUDD treatment than CON in batch 2, but not in batch 1 and 3 (mortality (% of litter size) in batch 2: CON: 11.8 ± 3.7%, DRYUDD: 2.0 ± 2.0%; $\chi^2_{2,39} = 18.3$, $P < 0.001$).

The majority of the dead piglets died before they received milk (65.2 ± 13.9%) and litters in DRY and CREEP had the lowest percentage of piglets in this category ($\chi^2_{5,39} = 11.5$, $P < 0.05$). Significantly fewer piglets were crushed before receiving milk in CON compared to CREEP, UDDER and

Table 1
Causes of postnatal mortality in the different treatments (mean ± S.E.).

	Treatment						Treatment		Batch		Interaction B*T
	CON	CREEP	UDDER	DRY	DRYCREEP	DRYUDD	$\chi^2_{5,39}$	*P* value	$\chi^2_{2,39}$	*P* value	*P* value
Postnatal mortality*	7.9 ± 2.1^{b}	11.5 ± 2.1^{ab}	15.1 ± 3.8^{a}	9.7 ± 2.7^{ab}	7.1 ± 2.7^{b}	9.3 ± 3.5^{ab}	75.2	<0.001	9.2	<0.05	<0.001
Sow parity	2.7 ± 1.0	2.4 ± 0.8	2.4 ± 0.9	3.1 ± 1.1	2.6 ± 0.9	3.0 ± 0.7	8.4†	ns	1.1†	ns	ns
Litter size (number)	13.3 ± 05^{b}	14.5 ± 0.5^{ab}	14.8 ± 0.6^{ab}	13.8 ± 0.8^{ab}	12.6 ± 0.7^{b}	14.9 ± 0.6^{a}	21.2†	<0.05	4.5†	<0.05	ns
Stillborn (% of total born)	4.0 ± 2.1	5.1 ± 1.2	6.0 ± 2.0	5.2 ± 1.7	6.5 ± 2.1	6.2 ± 1.9	5.2	ns	0.6	ns	ns
Farrowing duration (min)	248 ± 13.3^{a}	285.7 ± 8.7^{b}	273.1 ± 9.5^{ab}	272.5 ± 5^{b}	280 ± 1.8^{b}	386.2 ± 20.8^{c}	58.3†	<0.001	1.1†	ns	ns
Dead no milk*	3.9 ± 1.9^{ab}	1.6 ± 0.8^{a}	5.4 ± 1.7^{b}	1.4 ± 1.3^{a}	2.3 ± 1.2^{ab}	6.0 ± 2.1^{b}	12.7	<0.05	0.1	ns	ns
Dead milk*	2.0 ± 0.8^{a}	2.0 ± 1.1^{a}	3.8 ± 1.9^{a}	2.8 ± 1.0^{a}	3.3 ± 2.2^{a}	0 ± 0^{b}	7.1	<0.05	1.5	ns	ns
Crushed no milk*	0.5 ± 0.3^{a}	4.9 ± 1.8^{b}	3.2 ± 1.9^{b}	1.3 ± 0.6^{ab}	1.5 ± 1.1^{ab}	2.7 ± 1.2^{b}	18.9	<0.01	5.4	ns	ns
Crushed milk *	1.5 ± 0.8	3.0 ± 1.3	2.8 ± 1.4	4.2 ± 1.4	0.0 ± 0.0	0.6 ± 0.6	0.1	ns	17.8	<0.05	ns

Different superscript denotes significant differences between treatments. * % of litter size †F values from GLM.

DRYUDD ($\chi^2_{5,39}=18.9$, $P<0.01$; Table 1). Batch 1 had a higher postnatal mortality than batch 2 and 3 ($\chi^2_{5,39}=35.1$, $P<0.001$). When merging all six treatments from the three batches into three classes, (1) Control, (2) NoDry (CREEP + UDDER) and (3) Dried (DRY + DRYCREEP + DRYUDD), there were higher postnatal mortality in NoDry compared to Control and Dried ($\chi^2_{2,29}=32.1$, $P<0.001$).

Postnatal mortality was lower when there were fewer piglets per teat in a litter ($\chi^2_{1,39}=27.6$, $P<0.001$; Fig. 2). Higher birth weight ($\chi^2_{1,39}=29.1$, $P<0.001$), a shorter latency from birth to first suckle ($\chi^2_{1,39}=8.0$, $P<0.01$; Fig. 3), and a higher rectal temperature at 2 hours after birth ($\chi^2_{1,39}=12.4$, $P<0.001$; Fig. 4) were all associated with a lower piglet mortality. An increased litter size resulted in an overall higher postnatal mortality ($\chi^2_{1,39}=48.4$, $P<0.001$), both before receiving milk ($\chi^2_{1,39}=18.2$, $P<0.001$) and after receiving milk ($\chi^2_{1,39}=8.2$, $P<0.01$).

3.2. Teat success

Latency from birth to first suckle (average: 62 ± 1.9, range: 1–496 min) was shortest in DRYUDD, followed by UDDER ($F_{5.694}=5.8$, $P<0.001$; Table 2). Latency to first suckle was also shorter when there were fewer piglets per teat ($\chi^2_{1,39}=23.2$, $P<0.01$; Fig. 2), in piglets with higher birth weight ($F_{1.694}=18.2$, $P<0.001$), a higher weight at 2 hours ($F_{1.694}=17.4$, $P<0.001$), and in piglets with higher rectal temperature at 2 hours after birth ($F_{1.694}=8.1$, $P<0.01$; Fig. 4). Increased litter size tended to increase latency to first suckle ($F_{1.694}=6.9$, $P<0.1$). Piglets had a shorter latency to suckle in batch 2 compared to batch 1 and 3 ($F_{2.694}=9.8$, $P<0.001$).

3.3. Rectal temperature

Piglets in CREEP had a lower heat loss from birth until 2 hours compared to the other treatments ($F_{5.716}=6.5$, $P<0.01$), but there was no effect of treatment on heat loss from birth until 24 hours (Table 2). Heat loss until 2 hours after birth was smaller in piglets born early in the litter ($F_{5.716}=11.2$, $P<0.001$), in heavier piglets ($\chi^2_{1,39}=59.1$, $P<0.001$), and in piglets with shorter latency to suckle ($\chi^2_{1,39}=11.2$, $P<0.01$). Increased litter size decreased heat loss from birth until 2 hours ($F_{1.716}=14.3$, $P<0.001$), especially in CREEP ($F_{5.716}=5.7$, $P<0.001$). Piglets of first and

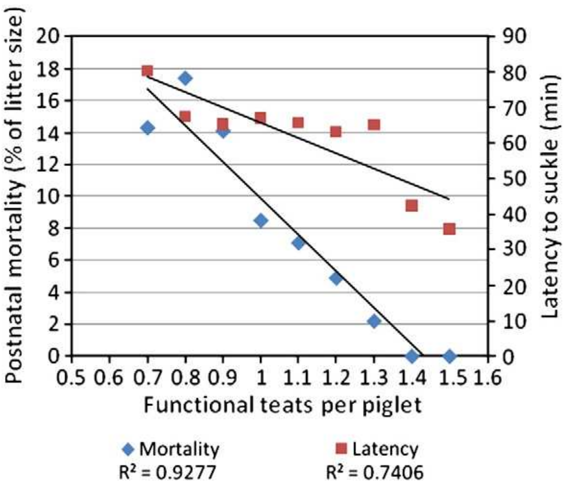

Fig. 2. Effect of teats per piglet on latency to suckle (min) and postnatal mortality (% of litter size).

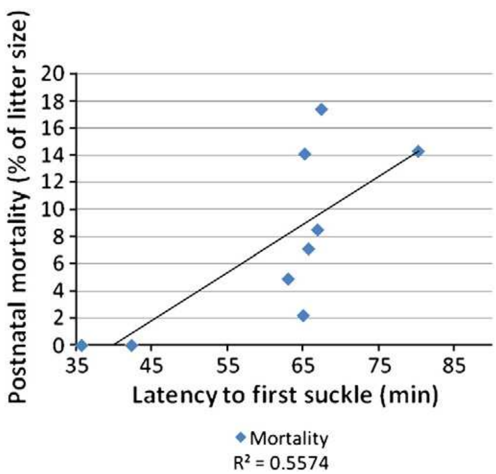

Fig. 3. Effect of latency to suckle on postnatal mortality (% of litter size).

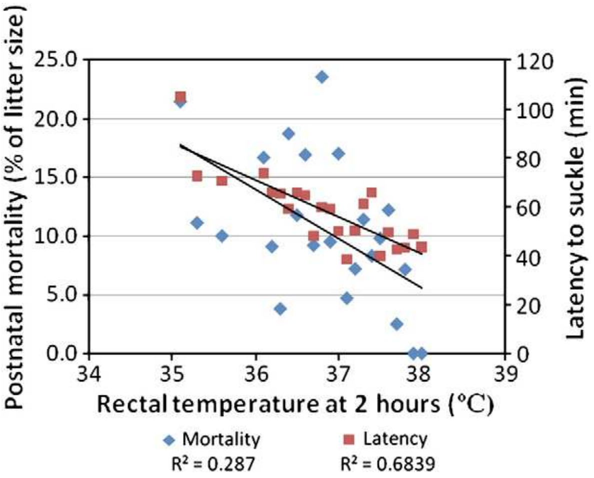

Fig. 4. Effect of rectal temperature at 2 hours on latency to suckle (min) and postnatal mortality (% of litter size).

second parity sows had the highest drop in rectal temperature from birth to 2 hours ($F_{2.716}=7.8$, $P<0.01$).

3.4. Weight gain

Piglets in CREEP had the lowest weight gain from birth to 2 hours ($F_{5.728}=3.2$, $P<0.01$), while at 24 hours, the piglets in CREEP, UDDER and DRY had a lower weight gain compared to the other treatments ($F_{5.728}=8.9$, $P<0.001$, Table 2). Weight gain until 24 hours was higher in piglets born early in the litter ($F_{1.728}=15.2$, $P<0.001$).

4. Discussion

The three treatments that included drying the piglets all had postnatal mortality below 10%, supporting previous findings that reduced heat loss after birth is one of the key factors for early piglet survival (Baxter et al., 2008; Pedersen et al., 2008). However, contrary to earlier findings (McGinnis et al., 1981; Christison et al., 1997; Andersen et al., 2009), there were no clear differences in postnatal mortality between the control treatment and the three dried treatments. The control treatment in the present study was handled in order to compare the weight gain and temperature development, and this stimulation was perhaps enough to increase piglet viability and reduce potential differences between treatments. It could be argued that the control treatment resulted in less disturbance of the sow and that this could explain the good results. However, overall sows in Norwegian herds are quite used to being handled and interact with the stock person during the lactation period (e.g. Andersen et al., 2007), and there was no situations with aggression towards the experimenter when conducting the treatments in the present study.

The highest postnatal mortality was found in litters that were placed at the udder without being dried first. Although the control piglets were not dried either, the litter size in the control treatment was on average 1.5 piglets less per litter compared to the latter. Placing piglets in the creep area, in particular without drying them first, had clear negative effects on latency to suckle and weight gain, both of which is important for piglet survival. However, the mortality was still lowest in the DRY and DRYCREEP treatments compared to the other treatments, but not the control treatment. This is contrast to Andersen et al. (2009) who documented much lower mortality when piglets were either placed directly in the creep area immediately after birth or both dried and placed under the heat lamp compared to control litters. The less clear effects of the treatments in the present study may be explained by the suboptimal design of the creep area and the exceptionally high litter sizes in some of the treatments. The sows were commonly observed resting towards the entrance of the creep area and thus blocking the piglets from getting to the udder. In fact, time to first suckle for piglets that were just placed in the creep area without drying them first, was twice as long compared to litters that were placed at the udder. If we look at all results together and the results from other studies (Andersen et al., 2007, 2009), we may still conclude that routines to reduce heat loss such as drying and helping the piglets to the udder or placing them under the heat lamp would be beneficial for survival provided that the piglets have free access to the creep area. In the DRYUDD treatment the mean litter size was almost 15, but nonetheless mortality was below 10%, which is remarkably well for loose-housed sows.

Large litter sizes had a negative effect on most of the parameters measured in this experiment; increased mortality both before and after milk intake, increased latency to suckle and reduced weight gain. Any positive effects of being placed at the udder may thus have been camouflaged by the negative effects of increased litter competition at the udder. On the

Table 2
Teat success, weight gain and temperature development in the six treatments.

	CON	CREEP	UDDER	DRY	DRYCREEP	DRYUDD	$F_{5,728}$	P value
Latency to suckle (min)	59.3 ± 3.9^{a}	96.3 ± 4.5^{b}	41.6 ± 4.8^{c}	57.4 ± 3.4^{a}	77.7 ± 5.9^{d}	43.2 ± 3.2^{c}	5.8	<0.001
Weight at birth (kg)	1.5 ± 0.1	1.5 ± 0.0	1.4 ± 0.2	1.4 ± 0.1	1.5 ± 0.1	1.4 ± 0.1	7.8	ns
Weight at 2H (kg)	1.59 ± 0.1^{a}	1.50 ± 0.1^{b}	1.51 ± 0.1^{b}	1.44 ± 0.1^{b}	1.67 ± 0.1^{a}	1.48 ± 0.2^{b}	6.4	<0.01
Weight gain birth – 2H (g)	42.9 ± 12.2^{a}	-29.4 ± 9.4^{b}	19.8 ± 9.1^{a}	21.2 ± 11.0^{a}	24.7 ± 11.3^{a}	16.8 ± 10.2^{a}	3.2	<0.01
Weight at 24H (kg)	1.71 ± 0.1^{a}	1.59 ± 0.1^{b}	1.56 ± 0.1^{b}	1.54 ± 0.1^{b}	1.78 ± 0.2^{ac}	1.60 ± 0.2^{b}	7.7	<0.01
Weight gain birth - 24H (g)	163.8 ± 18.1^{a}	61.3 ± 11.2^{b}	64.2 ± 10.1^{b}	84.1 ± 15.0^{b}	128.1 ± 16.0^{c}	118.7 ± 18.4^{bc}	8.9	<0.01
Temperature at birth (°C)	37.8 ± 0.2^{a}	37.9 ± 0.8^{a}	38.0 ± 0.1^{b}	37.1 ± 0.5^{a}	37.8 ± 0.2^{a}	38.0 ± 0.2^{b}	8.2	<0.001
Temperature at 2H (°C)	36.8 ± 0.1^{a}	37.1 ± 0.1^{b}	37.1 ± 0.1^{b}	36.6 ± 0.2^{a}	37.1 ± 0.1^{a}	37.4 ± 0.1^{b}	8.2	<0.01
Diff temp birth − 2H (°C)	-1.0 ± 0.1^{a}	-0.6 ± 0.0^{b}	-0.8 ± 0.1^{a}	-1.0 ± 0.1^{a}	-0.7 ± 0.1^{ab}	-0.8 ± 0.0^{ab}	6.5	<0.01
Temperature at 24H (°C)	37.7 ± 0.1	37.7 ± 0.1	37.9 ± 0.1	37.5 ± 0.1	37.8 ± 0.2	37.7 ± 0.1	1.2	ns
Diff temp birth − 4H (°C)	0.04 ± 0.1	-0.02 ± 0.0	-0.2 ± 0.1	-0.1 ± 0.1	0.1 ± 0.0	-0.3 ± 0.1	1.7	ns

Different superscripts denote significant differences between treatments.

other hand, heat loss was actually reduced in large litters, in particular when the piglets were placed in the creep area, which highlights the positive effects of social thermoregulation and external heat sources. It is interesting that piglets born from gilts and second parity sows had the highest heat loss at 2 hours as there were no significant differences in litter size or latency to suckle between the parities. This might be due to a smaller udder size to gain heat from and the lower milk production in younger sows compared to older sows (e.g. Eissen et al., 2000). Difference in litter size may also partly explain the varying postnatal mortality between the batches. However, the reduced mortality when piglets were dried and placed at the udder in batch 2, but not in batch 1 and 3, when litter size in this treatment was similar, illustrates just how complex this picture is. Despite the large litter sizes, there was an overall low piglet mortality of liveborn piglets in this study compared to the Norwegian average of 14.7% (Norsvin, 2008). The management on the present farm included a well functioning protocol around farrowing regarding cross-fostering, tooth grinding and provision of nest building material. In the commercial farm used in the study by Andersen et al. (2009), postnatal mortality was almost 20% prior to the study, and there was generally little systematic management around farrowing, with little or no nest building material provided. Provision of nest building material is documented to reduce piglet mortality and stimulate maternal behaviour (Cronin and van Amerongen, 1991; Herskin et al., 1998). These results indicate that it may be more difficult to further reduce postnatal mortality in a farm where the mortality is already at such a relatively low level.

Regardless of treatment, several piglet-related factors were highly important for survival, such as the number of functional teats per piglet, birth weight, the latency from birth to first suckle, and rectal temperature at 2 hours after birth. In addition to the direct negative effect on the piglet, these factors also likely interact with each other; fewer teats per piglet will increase latency to first suckle, which reduce weight gain and rectal temperature at 2 hours, which again reduce survival rate, especially in the lighter piglets in the litter. The negative consequence of reduced colostrum intake is also illustrated by the fact that the majority of the dead piglets died before receiving milk. Interestingly, there was no effect of piglet weight on percent of piglets crushed after receiving milk. Large litter size also reduce maternal investment and responsiveness to piglet scream (e.g. Wechsler and Hegglin, 1997; Andersen et al., 2005; Torsethaugen, 2008), which might partly explain the increase in crushings in larger litters. Knowing that increased litter sizes increases birth weight variability (e.g. Herpin et al., 1993; Canario et al., 2007), and that lighter piglets have a higher risk of dying (e.g. Tuchscherer et al., 2000), makes it even more important to focus on the negative effects of selecting for increased litter size. Considering that large litter sizes have a negative impact both on piglet related factors and on the maternal motivation in sows, the effect of these management routines will likely be reduced in large litters.

In conclusion, drying the piglets after birth and placing them at the udder resulted in reduced latency to suckle in all three batches, and a reduced postnatal mortality in batch 2, but not in the other two batches. Despite having the largest mean litter size of the treatments, less than 10% of the piglets in DRYUDD died, which is very low for loose housed sows. Regardless of treatment, several piglet-related factors were found to be highly important for postnatal mortality, such as the number of functional teats per piglet, birth weight, the latency from birth to first suckle, and rectal temperature at 2 hours after birth.

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Increasing the piglets' use of the creep area—A battle against biology?

Guro Vasdal[a,*], Marit Glærum[a], Michala Melišová[b], Knut E. Bøe[a], Donald M. Broom[c], Inger Lise Andersen[a]

[a] Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, P.O. Box 5003 1432 Ås, Norway
[b] Department of Ethology, Institute of Animal Science, 104 00 Prague–Uhříněves, Czech Republic
[c] Centre for Animal Welfare and Anthrozoology, Department of Veterinary Medicine, University of Cambridge, Madingley Road, Cambridge CB3 0ES, UK

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ABSTRACT

Indoor farrowing systems are based upon the assumption that the newborn piglets will leave their mother after suckling and enter a heated creep area, but newborn piglets are motivated to remain close to the sow. Several creep area features attractive to piglets were used to attempt to increase time spent in the creep area the first two days after birth and to find out whether increased time spent in the creep area would affect early piglet mortality in farrowing pens. Forty-six loose-housed sows and their litters kept in individual farrowing pens were subjected to one of three creep area treatments; (1) control (CON); concrete floor in the creep area, (2) bedding (BED); an insulated and soft bedding in the creep area and (3) HUT; an insulated and soft bedding in the creep area plus an additional wall to increase the heat conserving capacity in the creep area. The pens were video-recorded from 0–72 h after birth and analysis was conducted from 08:00 h to 14:00 h and from 20:00 h to 02:00 h on each day. The attempts to make the creep area attractive did not increase the use of the creep area; piglets in the hut treatment spent less time in the creep area and more time resting near the sow than piglets in the CON and BED treatment. Improving the thermal comfort and increase the layer of bedding in the creep area did not increase time spent away from the sow, nor did it reduce piglet mortality. Quality of the creep area thus appears to have little impact on piglet survival.

1. Introduction

The domestic sow shows maternal behaviour similar to that of the wild boar (e.g. Jensen, 1986; Gustavsson et al., 1999), and under semi-natural conditions, domestic sows will leave the group to search for a suitable nest site 1–2 days prior to farrowing (e.g. Jensen, 1988). When a suitable nest site has been located, she excavates a hollow and collects suitable material to build a nest in it, spending typically 5–10 h on the construction (e.g. Wood-Gush and Stolba, 1982; Jensen et al., 1993). During the first two days after birth, the sow will spend 90% of her time in the nest, only leaving the nest for brief foraging trips (Stangel and Jensen, 1991). The piglets spend these first days after birth resting in close contact with the sow and littermates, leaving the nest only to defecate (Stangel and Jensen, 1991). Remaining in the nest after birth serves several adaptive functions for the piglets: it facilitates the development of the mother-young bond (Jensen and Redbo, 1987), it reduces the chance of becoming separated from the sow or being detected by predators, and perhaps more importantly, gaining warmth (Fiala and Hurnik, 1983) and food from the udder. As other altricial mammals, piglets are born without fur or brown adipose tissue so their thermoregulatory capacity is poorly developed during the first days after birth (e.g. Berthon et al., 1994; Herpin et al., 2002). Although hypothermia is rarely recorded as cause of death in commercial pig herds, it might often be the primary

* Corresponding author. Tel.: +47 64965103; fax: +47 64965101.
E-mail address: guro.vasdal@umb.no (G. Vasdal).

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cause of starvation and crushing (reviewed by Edwards, 2002), as hypothermia renders the piglet less able to find a teat or avoid overlying by the sow (English, 1993). Heat from the udder will reduce the amount of energy needed to maintain body temperature and the intake of colostrum provides a valuable energy source for thermoregulation (Herpin et al., 1994), which in turn may increase the piglets' chances of survival. Piglets in semi-natural conditions start following the sow on small foraging trips from 4 days after birth, and the sow and litter rejoin the group around 10 days after farrowing (Newberry and Wood-Gush, 1988; Jensen, 1988).

Unlike the sow–piglet interactions observed in semi-natural conditions, where the sow leaves the piglets in the nest, modern farrowing systems are based on the principle that newborn piglets will leave the sow and enter a heated creep area. In this system, room temperature in the farrowing unit is kept within the sows' thermal comfort zone, around 20 °C, while a suitable microclimate (30–34 °C) to avoid hypothermia in piglets is provided in the creep area. However, numerous studies have found that young piglets prefer to huddle near the sow and littermates despite unfavourable thermal conditions in the sow area, instead of staying in the creep area during the first days after birth (e.g. Hrupka et al., 1998; Andersen et al., 2007; Moutsen et al., 2007; Vasdal et al., 2009). In fact, Hrupka et al. (2000) found that piglets were more attracted to an anesthetized piglet in a cold chamber than to an empty warm chamber, suggesting that the attraction to physical contact is stronger than the attraction to ambient heat. The piglets only start using the creep area to a substantial extent from day 3 after birth (e.g. Hrupka et al., 1998; Berg et al., 2006; Vasdal et al., 2009), which is the age when they would naturally start exploring the nest surroundings together with the sow (e.g. Stangel and Jensen, 1991).

Despite the piglets' motivation to lie close to the sow, many farmers' constructions and scientific studies have been aimed at increasing the attractiveness of the creep area while the use of the creep area in farrowing crates has been increased by: reducing temperature in the sow area (Zhou and Xin, 1999; Schormann and Hoy, 2006; Burri et al., 2009), adding a warm water bed in the creep area (Ziron and Hoy, 2003) or providing a simulated udder in the creep area (Lay et al., 1999; Toscano and Lay, 2005). Piglets in farrowing crates spend more time in the creep area than piglets in farrowing pens, possibly because the sow area is made less attractive by slatted floors, horizontal bars around the sow and reduced space (Blackshaw et al., 1994; Vasdal et al., 2009). Another reason for this difference might be the extra attraction of the sow area to piglets resulting from higher maternal motivation displayed by sows in farrowing pens showing more piglet-directed behaviour, higher responsiveness to piglet screams and increased nursing behaviour (e.g. Cronin et al., 1996; Arey and Sancha, 1996; Jarvis et al., 2005). Vasdal et al. (2010) found that 24-h-old piglets preferred 42 °C to other, lower infrared temperatures, and a thick layer of sawdust to both a foam mattress and a water mattress. Thus, it might be possible to increase the use of the creep area in loose-housed sows by combining a thick layer of sawdust with high infrared temperatures. However, although previous studies have shown that piglets in farrowing crates spend more time in the creep area than piglets in farrowing pens, a relationship between increased time spent in the creep area and piglet mortality has not yet been documented. This information would be important to the ongoing work of reducing piglet mortality in loose-housed sows.

The aim of this study was to investigate, firstly, whether improving the thermal comfort and softness of the creep area would increase time spent in the creep area during the first three days after birth, and secondly, whether this would affect early piglet mortality in loose-housed sows.

2. Material and methods

2.1. Experimental design

Loose-housed sows and their litters kept in individual farrowing pens were subjected to one of three creep area treatments during the first three days after farrowing (0–72 h); Control (CON); concrete floor in the creep area, bedding (BED); an insulated and soft bedding in the creep area and HUT; an insulated and soft bedding in the creep area, in addition to an extra wall, to increase the heat conserving capacity in the creep area. During four farrowing batches, a total of 46 sows were randomly allotted to one of the treatment pens: CON ($n = 17$), BED ($n = 15$) and HUT ($n = 14$) six days before expected farrowing.

2.2. Animals and housing

This experiment was conducted at the Pig Research Unit at the Norwegian University of Life Sciences. All sows were Yorkshire × Norwegian Landrace with parities ranging from 1 to 8 (mean ± S.E: 2.7 ± 0.2) and inseminated with semen from Duroc × Landrace boars. The sows were moved from the group housing gestation unit to the farrowing unit at day 110 post-insemination. The farrowing unit where the farrowing pens were located was insulated and mechanically ventilated and the air temperature was kept at 20 °C until farrowing, and then reduced to 16 °C.

Each farrowing pen measured 8.9 m^2 in total, and the sow area (part of the pen accessible to the sow) measured 7.0 m^2 with 3.7 m^2 slatted plastic floor (Fig. 1). The creep area measured 1.9 m^2, of which 1.0 m^2 was covered with a wooden ceiling. The creep area was separated from the sow area by a diagonal wall (2 m × 1 m) with a 20 cm gap along the bottom for piglets to enter. This diagonal wall was located 30 cm from the wooden ceiling in the creep area (Fig. 1). The solid floor in the sow area was covered by a 2 cm layer of sawdust in all three treatments, and all pens were cleaned out twice a day. The creep areas were maintained according to the treatment requirements.

The sows were fed to appetite with a standard lactation concentrate at 08:00 h and 14:00 h, in addition to 0.5 kg of roughage twice a day. From day 113 until farrowing the sows got 2.0 kg of straw daily for nest building. Lights were kept on for 24 h to allow video recording.

To avoid interference with the treatments, no assistance was given to newborn piglets at the time of farrowing.

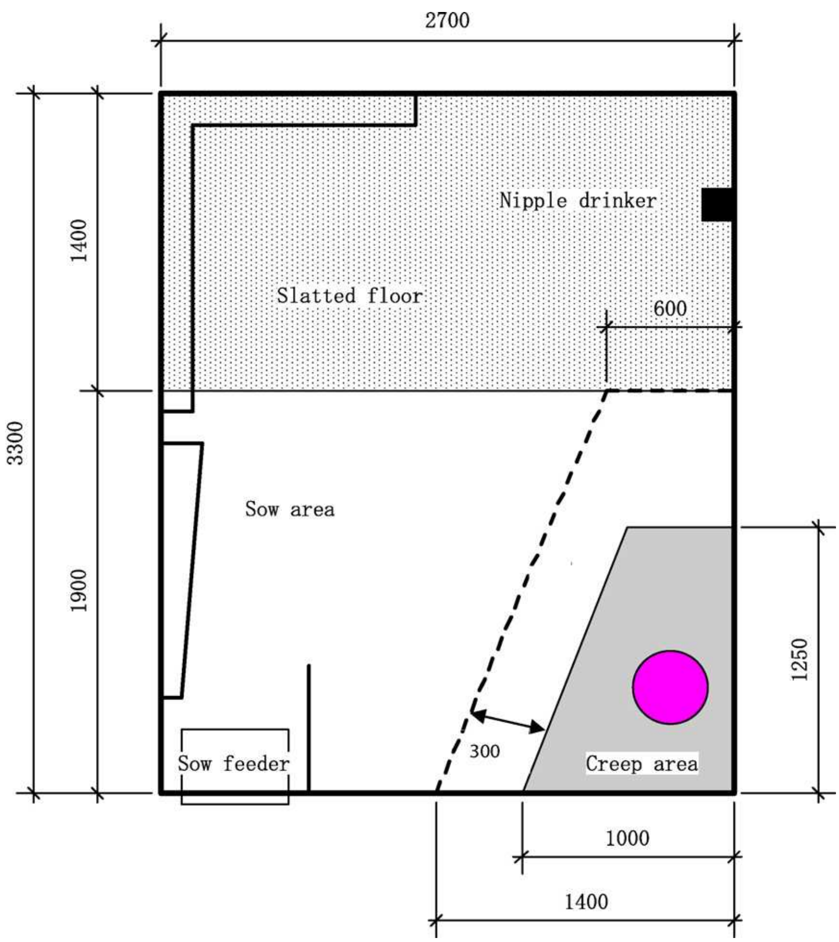

Fig. 1. The farrowing pen, creep area with heat lamp in the ceiling. All measures in mm.

During the first day after farrowing the piglets were individually weighed, ear tattooed, given iron injection and teeth grinded. Male piglets were castrated around day 5. Piglets in the largest litters were cross-fostered to the smaller litters between 12 h and 24 h after birth, so that no sow had more piglets than the number of functional teats. Piglets were cross-fostered equally within and between the treatments. Litter size in this study is thus number of live-born piglets fostered off + piglets fostered on from other sows.

Piglets not able to survive because of injuries or starvation were humanely euthanized by the staff and all dead piglets were subjected to a post mortem to determine cause of death. The dead piglets were categorized as stillborn (lungs sink in water), dead without milk in the stomach (lungs float, no milk in stomach), dead with milk in their stomach (lungs float, milk in stomach), crushed without milk in the stomach (physical signs of crushing, no milk in stomach) and crushed with milk (physical signs of crushing, milk in stomach). A physical sign of crushing included bruising to the body, cranial bone fractures, haemorrhages or crushed internal organs. In addition to the physical signs, the video recordings were used to document crushings.

2.3. The creep areas

All three creep area treatments had floors made of standard concrete, and a ceiling made of solid wood 65 cm above the floor. The creep areas were heated by a red infrared 250 W heat lamp mounted in the wooden ceiling. The infrared temperature was regulated by an infrared (IR) temperature controller (Model VE122S IR Controller, Veng Systems®, Roslev, Denmark) using an IR temperature sensor (Model VE181-50, Veng Systems®). The set-point infrared temperature in the creep area was 34 °C; however, as the heat lamp was unable to provide this temperature, the infrared temperature in the creep area remained at around 30 °C.

The different creep areas treatments were as follows:

CON: the concrete floor in the creep area was sprinkled with <100 g of sawdust, a similar amount to that used in commercial herds.

BED: Insulated and soft bedding: i.e. a thick layer of sawdust (7–10 cm) covered the entire concrete floor in the creep area.

Table 1
Piglet location (% of observations) in areas of the pen (means ± S.E).

	Treatment			Day after birth			Creep area features		Day after birth		Interactions treatment × day
	CON (n = 17)	BED (n = 15)	HUT (n = 14)	Day 0	Day 1	Day 2	$F_{2.88}$	P-value	$F_{2.88}$	P-value	P-value
In Creep	28.8 ± 4.5	30.4 ± 4.7	17.0 ± 5.0	17.0 ± 1.9	23.7 ± 3.2	38.3 ± 4.0	10.8	<0.001	6.8	<0.01	<0.05
Nursing	27.3 ± 2.0	24.8 ± 1.6	25.0 ± 2.3	37.8 ± 1.9	22.5 ± 1.3	16.2 ± 0.8	1.5	ns	50.8	<0.001	ns
Active sow area	10.3 ± 1.1	9.7 ± 0.7	12.4 ± 1.2	13.1 ± 0.9	11.4 ± 1.2	8.4 ± 0.6	1.9	ns	13.6	<0.01	<0.05
Resting alone	2.3 ± 0.7	3.6 ± 2.6	1.3 ± 0.4	1.5 ± 0.3	1.4 ± 0.4	1.8 ± 0.5	0.7	ns	0.7	ns	ns
Resting near sow	31.2 ± 2.9	31.3 ± 4.5	44.0 ± 4.2	30.1 ± 1.9	41.1 ± 2.8	35.1 ± 3.5	3.0	0.5	2.7	ns	<0.001

HUT: In addition to a thick layer of sawdust (7–10 cm) on the concrete floor, an extra diagonal wall with an entrance (20 cm × 40 cm) was added in the creep area to provide a better covered area without draught, with a more stable, higher infrared temperature. The infrared temperature in HUT was around 2 °C higher than in CON and BED treatments.

2.4. Behavioural observations

The sows were continuously video-recorded from 2 days before farrowing until 3 days after farrowing. A video camera was suspended over each pen and connected to a computer using the MSH video system (M.Shafro & Co., www.guard.lv). The behaviour of the piglets and their location in the pen was scored using instantaneous sampling every 10 min from 08:00 h to 14:00 h (6 h) and from 20:00 h to 02:00 h (6 h) at day 0 (0–24 h), day 1 (25–48 h) and day 2 (49–72 h), adding up to a total of 216 observations per litter. The video analysis of each litter began at 08:00 h on the morning after the farrowing was finished. These two periods were chosen due to the presumed high activity at 08:00–14:00 h, and presumed low activity at 20:00–02:00 h. In order to score the location of the piglets, the farrowing pen was divided into two zones: the creep area and the sow area (the rest of the pen).

The behaviour and location of piglets was scored using the following categories:

Number of piglets:

1. In the creep area.
2. Suckling (actively sucking on a teat).
3. Active in sow area (standing/walking/running/exploring etc.).
4. Piglet resting alone in sow area without body contact with sow or littermates.
5. Resting in contact with the sow or littermates.

2.5. Statistical methods

In the analysis, the litter was used as the statistical unit. The differences in piglet behaviour and location between treatments and days were analysed using a Glimmix model procedure in SAS software with Poisson distribution, including the following class variables: treatment (CON, BED, HUT), batch (1, 2, 3 and 4), days after farrowing (0, 1, 2) and sow parity (1–8). The interactions between treatment × batch and treatment × day were also included in the model. Sow was included as a random effect, and litter size was included as a continuous variable in the model. Piglet mortality and causes of mortality were analysed using a Genmod procedure in SAS with Poisson distribution including the following class variables and their interactions: treatment (CON, BED, HUT), batch (1, 2, 3, 4), days after farrowing (0, 1, 2) and sow parity (1–8), with litter size and birth weight included as a continuous variable. Due to the lack of normal distribution, relationships between piglet location and piglet mortality were analysed by a Spearman Rank correlation analysis.

3. Results

3.1. Piglet location in the pen

Piglets in the HUT treatment spent less time (% of observations) in the creep area than piglets in the CON and BED treatments ($F_{2.88}$ = 10.8, P < 0.001), while there was no difference in time spent (% of obs) in the creep area between the CON and BED treatment (Table 1). The number of piglets lying in the creep area increased in the first two days after farrowing ($F_{4.88}$ = 6.8; P < 0.01), and this increase was highest in the BED treatment ($F_{4.88}$ = 2.7; P < 0.05) (Fig. 2). There were large differences between litters within the same treatment in how much time they spent (% of obs) in the creep area; the litters ranged from 2% to 72% of the observations in all three treatments. Use of the creep area was not significantly affected by sow parity, birth weight or litter size.

A higher percentage of piglets rested near the sow in the HUT treatment than in the CON and BED treatment ($F_{2.88}$ = 3.0, P = 0.05) (Table 1). The percentage of piglets

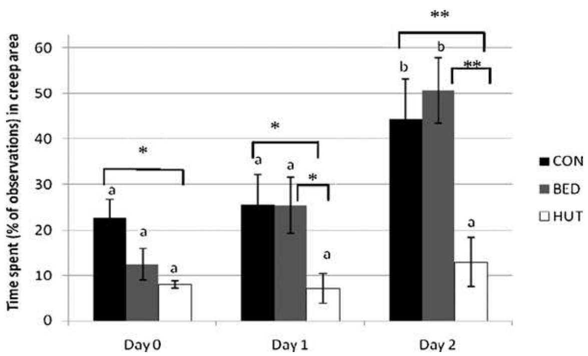

Fig. 2. Changes in time spent (% of observations) in creep area (mean ± S.E.) in the three treatments during the first three days after birth. Difference between days within treatment: a, b, c: P < 0.05. Difference within day between treatments: $^{*}P$ < 0.05, $^{**}P$ < 0.01.

Table 2
Piglet mortality (% of live born) in the three different creep areas (means ± S.E).

	Treatment			Creep area features	
	CON (n = 16)	BED (n = 14)	HUT (n = 12)	$\chi^2_{2,29}$	P-value
Litter size (number)	12.4 ± 0.4	13.0 ± 0.2	12.9 ± 0.4	0.0	ns
Stillborn*	6.2 ± 2.1	6.0 ± 2.4	5.3 ± 2.7	0.1	ns
Birth weight (kg)	1.6 ± 0.1	1.4 ± 0.1	1.5 ± 0.1	0.0	ns
Total mortality**	13.4 ± 3.9	12.9 ± 3.2	15.2 ± 3.3	2.9	ns
Dead other causes	8.1 ± 2.1	3.1 ± 1.2	9.9 ± 2.5	31.0	<0.01
Crushed total	5.2 ± 2.6	9.2 ± 2.9	8.2 ± 3.5	2.6	ns

* % of total born piglets.
** % of live-born piglets.

suckling, being active near the sow or resting alone were not affected by the treatments. During the first three days after birth the piglets decreased the time spent (% of obs) suckling ($F_{2.88}$ = 50.8; P < 0.001) and the time spent (% of obs) active in the sow area ($F_{2.88}$ = 13.6; P < 0.01).

Increased litter size reduced both the time the piglets spent (% of obs) resting alone ($F_{1.88}$ = 5.1, P < 0.05) and the time they spent (% of obs) resting near the sow ($F_{1.88}$ = 5.5, P < 0.05). Piglet location in the pen was affected by sow parity; litters of sows with parity 6 used the creep area more than any other parity ($F_{7.88}$ = 2.4, P < 0.05), while piglets of sows with parity 7 spent more time (% of obs) active near the sow ($F_{7.88}$ = 2.7, P < 0.05) than in the other parities. Sow had a significant effect on time spent (% of obs) in the creep area (t = 2.4, P < 0.05), time spent (% of obs) nursing (t = −5.8, P < 0.001) and time spent (% of obs) active in the sow area (t = −2.4, P < 0.05).

The percentage of piglets resting alone were higher in batch 1 than in the other batches ($F_{3.88}$ = 6.4, P < 0.05), while the percentage of piglets resting together with the sow were higher in batch 2 than in the other batches ($F_{3.88}$ = 5.5, P < 0.01). There was a significant interaction between batch and treatment on time spent (% of obs) active in the sow area ($F_{6.88}$ = 2.7, P < 0.05). However, there were no clear trends in the direction of these effects.

3.2. *Piglet mortality*

There were no significant differences in piglet mortality among the three treatments (Table 2). Neither sow parity, number of live-born piglets nor piglet birth weight differed significantly among the treatments. The overall piglet mortality in the study was 13.8 ± 3.4% of live born, of which 9.4 ± 1.9% died before receiving milk and 4.4 ± 1.5% died after receiving milk. There was no significant difference between the treatments in percentage of piglets dying before or after milk intake. There were no significant differences among the treatments in the percentage of piglets being crushed by the sow (Table 2). Fewer piglets died of causes other than crushing in the BED treatment than in the CON and HUT treatment ($\chi^2_{2,29}$ = 31.0, P < 0.01) (Table 2). In the CON treatment, piglets were crushed in 37% of the litters, while piglets died of other causes in 68% of the litters. These values were 50% of the litters (crushed) and 37% of the litters (other causes) in the BED treatment, and 31% of the litters (crushed) and 50% of the litters (other causes) in the HUT treatment, respectively. Piglet mortality was reduced from 9.5 ± 1.9% of the live born on day 0, to 6.5 ± 1.7% on day 1 and 3.0 ± 0.7% on day 2 (Fig. 3). Neither litter size nor birthweight had an effect on piglet mortality in this study.

The four batches did not differ in sow parity, litter size or birth weight. Batch 1 had a higher mortality rate ($\chi^2_{3,29}$ = 17.7, P < 0.01) and a higher percentage of stillborn piglets ($\chi^2_{3,29}$ = 9.5, P < 0.05) compared to the other three batches. There was no significant interaction between batch and treatment on piglet mortality. Piglet mortality was affected by sow parity; parity 3 (n = 6) and 5 (n = 5) had the highest piglet mortality, while parity 1 (n = 12) and 6 (n = 2) had the lowest piglet mortality ($\chi^2_{7,29}$ = 56.7, P < 0.001).

The total time spent (% of obs) in the creep area was not significantly related to piglet mortality in any of the treatments on day 0, day 1 or day 2. There was no relationship between mortality and time spent (% of obs) resting near the sow, resting alone or being active near the sow.

4. Discussion

Improving the thermal comfort and softness in the creep area neither increased the use of the creep area, nor was there any relationship between use of the creep area and piglet mortality. The creep area has long been considered an important part of the farrowing environment, providing the piglets with a suitable microclimate and physical protection from the sow, however, it appears difficult to attract

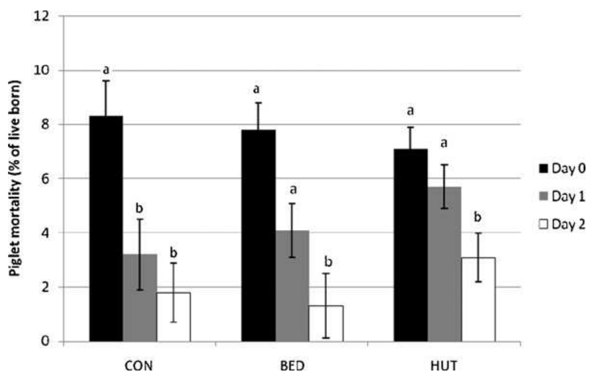

Fig. 3. Piglet mortality (mean ± S.E.) in the three treatments during the first three days after birth. Difference between days within treatment: a, b: P < 0.05.

newborn piglets away from the sow. The hut was actually least used of the three creep areas, opposite to what was predicted based on previous findings; that piglets are attracted to warm and soft areas when the sow is crated (e.g. Zhou and Xin, 1999; Schormann and Hoy, 2006; Burri et al., 2009) and in piglet preference tests (e.g. Hrupka et al., 2000; Vasdal et al., 2010). In total, the piglets in the present study spent less than a third of their time in the creep area, thus none of the three creep area treatments were able to attract the piglets away from the sow to a greater extent than reported in other studies of loose-housed sows (e.g. Berg et al., 2006; Vasdal et al., 2009). This can be explained by the fact that piglets are strongly motivated to lie close to the sow and litter mates early after birth regardless of the presence of a heated creep area (Hrupka et al., 1998; Andersen et al., 2007; Moutsen et al., 2007). Lying close to the sow after birth is a highly adaptive behaviour as staying close to the udder increases the piglets' chance of survival, and it can therefore be considered as a battle against biology to aim at attracting newborn piglets away from the sow. Earlier studies have suggested that variations in the sows' maternal behaviour may explain differences in the piglets' behaviour (e.g. Berg et al., 2006), but it is not clear if and how the sow encourages the piglets to use the creep area. From a biological point of view, improved maternal behaviour should in fact increase the piglets' attraction to the sow and would thus increase the time spent together with the sow, rather than the opposite.

In accordance with previous findings (e.g. Berg et al., 2006), there were large differences between litters in use of the creep area. However, there was no relationship between time spent in the creep area and piglet mortality. If increased use of the creep area was positive for piglet survival, differences in mortality should be expected between litters with high and low use of creep area. Vasdal et al. (2009) found that piglets in crates spent significantly more time in the creep area than piglets in pens, however, there were no differences in mortality between these environments (Pedersen et al., in preparation). These results suggest that the creep area is less important for piglet survival than previously thought. Contrary to previous studies (e.g. Weary et al., 1996), there was no relationship between time spent resting near the sow and piglet mortality in the present study. Thus it might be other factors, such as the physical state of the piglet like birthweight and body temperature (e.g. Pedersen et al., 2008) that explains early piglet mortality. Although mortality was not affected by birth weight in the present study, a majority of the piglets died before receiving milk, suggesting that starvation was a major predisposing factor for the mortality. Surprisingly, litter size had no clear effect on mortality in this study, contrary to previous findings (e.g. Andersen et al., in preparation; Weber et al., 2009; Pedersen et al., 2006). The negative effects of large litter sizes in the present study might have been camouflaged by the cross fostering, as the sows never had more piglets than functional teats.

In conclusion, offering a heated creep area with soft bedding did not increase time spent away from the sow, nor did it reduce piglet mortality. Quality of the creep area thus appears to have little impact on piglet survival.

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Can sow pre-lying communication or good piglet condition prevent piglets from getting crushed?

Michala Melišová[a,*], Gudrun Illmann[a], Inger Lise Andersen[b], Guro Vasdal[b], Jiří Haman[c]

[a] Department of Ethology, Institute of Animal Science, 104 00 Prague-Uhříněves, Czech Republic
[b] Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, P. O. Box 5003, 1432 Ås, Norway
[c] Biometric Unit, Institute of Animal Science, 104 00 Prague-Uhříněves, Czech Republic

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ABSTRACT

This study focused on the impact of sow–piglet communication during pre-lying behaviour and piglet condition on piglet location before the sow was lying down and on the incidence of piglet crushing. Eighteen loose-housed, Yorkshire × Norwegian Landrace sows and their litters were studied on Day 1 and Day 3 post partum. The sow's pre-lying communication, consisting of the frequency of sow vocalization, sniffing and nudging piglets, was calculated per standing-to-lying event, and 260 events were analyzed. We also determined which component of the pre-lying behaviour influenced piglet location (piglets in an area identified as the danger zone and in the sow area) and piglet clustering at the moment of lying down. In contrast to what we predicted, sniffing increased the proportion of piglets (out of the litter size) in the danger zone ($P < 0.05$), sow area ($P < 0.05$) and piglet clustering ($P < 0.05$). Similarly, sow vocalization attracted the piglets to the sow and thus increased the proportion of piglets in the danger zone ($P < 0.05$). There was no effect of pre-lying communication, piglet location or piglet clustering on the incidence of crushing. Piglet mortality caused by crushing was 6.4% of live born piglets ($N = 15$). The frequency of pre-lying communication, such as sow vocalization decreased ($P < 0.0001$) and nudging tended to decrease ($P < 0.1$) from Day 1 to Day 3, whereas the frequency of sniffing remained stable. Piglets with higher birth weight were more likely to be present in the danger zone ($P < 0.0001$) on Day 1 whereas on Day 3 no effect of piglet weight was found. Rectal temperature had no effect on piglet presence in the danger zone on both days. The probability of crushing increased on Day 1 with decreasing piglet weight ($P < 0.05$). In conclusion, the more sows communicated with piglets, the more the piglets were attracted to stay in close proximity to the sow, however there was no association detected between sow pre-lying communication and piglet crushing. Close proximity of piglets to the sow during the first few days post partum outside the time of nursing seems likely to stimulate the mother–piglet bonding process while bringing benefits to piglets (heat, milk and protection) which might out weigh the risk of getting crushed by the mother.

1. Introduction

Piglet mortality represents an important economical and welfare problem in all housing systems for lactating sows. The vast majority of lactating sows on commercial pig farms are housed in farrowing crates which provide unsatisfactory living conditions for the sows but that have been

* Corresponding author. Tel.: +420 267 009 568; fax: +420 267 710 779.
E-mail addresses: melisovam@centrum.cz, melisova.michala@vuzv.cz (M. Melišová).

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considered an efficient way to decrease piglet mortality (Blackshaw, 1994; Bradshaw and Broom, 1999; Marchant et al., 2000). In contrast, recent results based on large sample sizes show that piglet mortality and its variability do not differ between conventional and loose farrowing systems (Weber et al., 2007; Pedersen et al., 2010). Several studies made in loose-housing systems allowing the sow to move around and communicate freely with her piglets show that maternal motivation and protectiveness have a large impact on piglet survival (Wechsler and Hegglin, 1997; Špinka et al., 2000; Marchant et al., 2001; Pitts et al., 2002; Andersen et al., 2005). Before lying down, sows perform specific types of pre-lying behaviour (e.g. Clough and Baxter, 1984; Blackshaw and Hagelso, 1990; Wischner et al., 2010) which might be functional by attracting piglets' attention and giving them enough time to move (e.g. Marchant et al., 1996). These types of behaviour are: rooting (Blackshaw and Hagelso, 1990; Špinka et al., 2000; Marchant et al., 2001; Valros et al., 2003; Pokorná et al., 2008; Burri et al., 2009; Wischner et al., 2010), pawing (Marchant et al., 2001; Pokorná et al., 2008; Wischner et al., 2010), sniffing piglets (Valros et al., 2003; Pokorná et al., 2008; Wischner et al., 2010), nudging piglets (Marchant et al., 2001), looking around (Marchant et al., 2001; Wischner et al., 2010), turning around (Burri et al., 2009) and descending vertically (Špinka et al., 2000). In a group farrowing system, increased incidence of sow's pre-lying behaviour decreased the occurrence of dangerous situations leading to crushing (Marchant et al., 2001). In crates, sows that have not crushed piglets perform pre-lying behaviour more often than sows that crush at least one piglet (Wischner et al., 2010). In contrast to this, some studies focusing on different pre-lying behaviours both in crated and loose-housed sows, did not find any relationship between pre-lying behaviour and probability of crushing (Pokorná et al., 2008), the incidence of near-crushing situations (Burri et al., 2009) or piglet mortality in general (Špinka et al., 2000). Valros et al. (2003) found lower piglet mortality due to crushing in indoor, loose-housed sows with increasing rooting activity, but sniffing piglets and other pre-lying behaviour was not significantly related to the incidence of crushing. According to Johnson et al. (2007), sows kept outdoors that did not crush any piglets spent more time pawing than sows that crushed some of their piglets. However, this was not the case for rooting behaviour with the snout directed towards the ground in a similar study with outdoor sows (Špinka et al., 2000). It is likely that communication through sniffing, nudging and vocalization have a larger impact on piglet location and the chances of getting crushed than the less focussed rooting or the nature of posture changes. These contradictory results question the function of these two behaviours as preparatory movements for lying down. Except for nest building, pawing is most commonly observed in relation to lying down movements (e.g. Johnson et al., 2007), whereas motivation for rooting is also high in pregnant sows and can be observed in a wide range of situations (e.g. Studnitz et al., 2007). Sows that do not crush any of their piglets respond sooner to piglet distress calls and sniff their piglets more than sows that crush several piglets (Andersen et al., 2005). Although there are several studies on vocal communication during nursing (e.g. Algers and Jensen, 1985; Blackshaw et al., 1996; Špinka et al., 2002) and offspring recognition (e.g. Illmann et al., 2002), vocal communication between sow and piglets, specifically before the sow lies down has, to our knowledge, not been documented.

Lying down events seem less likely to be dangerous when piglets are clustered together (Clough and Baxter, 1984; Marchant et al., 2001; Burri et al., 2009) as it is probably easier for the sow to locate the piglets and avoid piglet crushing. In contrast to this, Pokorná et al. (2008) did not find any influence of piglet clustering on probability of crushing in crated systems. However, the same study did find a positive effect of sniffing and pawing, but not rooting, on the degree of piglet clustering. Nevertheless, the relationship between different pre-lying behaviours and the incidence of crushing events still needs to be systematically studied. It can be discussed whether a high degree of sow–piglet communication attracts the piglet to stay close to the sow or whether this stimulates them to use the creep area sooner after birth. Recent results show that when the sow is kept loose, piglets spend most of their time close to the sow and not in the creep area for the first two days after birth (Berg et al., 2006; Vasdal et al., 2009, 2010), and the piglets spend less time in the creep area when the sow is kept loose than when crated (e.g. Vasdal et al., 2009). One of the reasons for this might be that this system allows the sow to communicate both physically and vocally with the piglets and therefore stimulates them to spend more time in close proximity. Historically, one of the goals is to safeguard piglets, thus keep them out of the potentially risky sow area, outside nursing times. However, time spent in the sow area in general does not affect piglet mortality (Berg et al., 2006; Vasdal et al., 2009, 2010), but more piglets present in close proximity to the sow when lying down is documented to increase the incidence of near-crushing events (e.g. Burri et al., 2009). This is thus an important distinction to make.

Birth weight and rectal temperature shortly after birth can be used as postnatal survival indicators (e.g. Baxter et al., 2009; Vasdal et al., 2010). Piglets with low weight gain are more likely to be crushed (e.g. Dyck and Swierstra, 1987) and spend more time in the risky area underneath a standing or sitting sow as they have a greater need for milk (Weary et al., 1996). Another explanation for this is that hypothermic or starving piglets might be sluggish or disorientated and are therefore less able to get away from near-crushing situations (e.g. Weary et al., 1996). Piglets with low vitality might respond less to communication initiated by the sow than strong and healthy piglets.

In this study we focused on the impact of sow-piglet communication during the pre-lying behaviour and piglet condition on piglet location before lying down on Day 1 and Day 3 post-partum (pp) and on piglet crushing. Specific aims were to; (i) determine whether sows that communicated more with their piglets had fewer piglets in the specified danger zone (area within one piglet length of the sow on the side on which she is about to lie down) and sow area and more piglets clustered, (ii) assess whether more sow pre-lying communication, lower proportion of piglets in the danger zone and sow area and higher proportion of piglet clustering decreased the probability of piglet crushing, (iii) assess the frequency of the sow pre-lying communication and; (iv) determine whether hypothermic piglets with a low weight were more likely to be present in the danger zone before the sow lay down and had a higher probability of crushing.

2. Materials and methods

2.1. Animals and housing

The experimental subjects were 22 Yorkshire × Norwegian Landrace, individually loose-housed sows which had farrowed at the Pig Research Unit at the Norwegian University of Life Sciences in 2009. Four of these sows were excluded from the study due to health problems (birth difficulties, MMA). All sows were inseminated with semen from Duroc × Landrace boars and moved from the indoor group gestation unit to the indoor farrowing unit at Day 110 post-insemination. Parities ranged from 1 to 7 (2.5 ± 1.8, mean ± SD). All farrowing pens were in the same building and each pen had a total area of 8.9 m^2, where part of the pen accessible to the sow measured 7.0 m^2 (resting area with solid floor measured 3.3 m^2, plastic, slatted floor measured 3.7 m^2). The creep area (1.9 m^2), inaccessible to the sow, had floor heating with a wooden triangular roof and was separated by a diagonal wall with a 0.20 m gap along the bottom for piglets to enter (Fig. 1). Two metal farrowing rails were fixed in the resting area and above the slatted floor to avoid piglet crushing (Fig. 1). The cleaning was conducted manually twice a day and 2.0 kg of straw was provided on a daily basis from Day 113 until farrowing. Thereafter the solid floor of the resting area and creep area were covered by 2 cm of fresh, clean sawdust every day. Water was available *ad libitum* from nipple drinkers placed over the slatted floor area both for the sow and her piglets. Commercial lactation diet and 0.5 kg of roughage (hay from the first harvest which was placed on the floor) were provided to the sows at 8.00 h and 14.00 h daily. The farrowing unit was automatically ventilated and the air temperature was maintained at around 16 °C. In order to enable the non-stop continuous video recording the artificial dim lights were kept on during the night. During the day-time natural light entered through windows. During the first 24 h after farrowing cross-fostering was carried out; piglets from large litters were moved to small litters, however no attempt to balance for piglet size within litter was made. Litter size was calculated as number of live born piglets minus piglets fostered off plus piglets fostered on from other sows. Litter size ranged from 5 to 17 (mean ± SD: 13 ± 2.9). Piglets had their teeth ground and received an oral dose of iron at 24 h old.

2.2. Behavioural observations

Eighteen sows and their litters were video recorded on Day 1 (from the end of farrowing until 24 h pp) and Day 3 (48–72 h pp). For each pen, one camera (Sony HD 1080; HD-SR 12), attached to a tripod, was positioned so sow and piglet behaviour in the pen could be recorded. A microphone, positioned 1.4 m above the floor in the middle of the sow area, was connected via cables to the camera.

2.2.1. Analysis of the sow pre-lying communication

Video analysis of sow pre-lying communication started 2 min before a sow began to lie down and the following behaviours were recorded during these 2 min: the frequency of vocalization, the frequency of sniffing and the frequency of nudging. Sow pre-lying communication was calculated based on the total frequencies of pre-lying behaviours occurring during that event (for definitions see Table 1a). We analyzed 10 standing-to-lying events per sow without external disturbance on Day 1 and on Day 3. Some sows had less than 10 standing-to-lying down events per day without external disturbance (11 sows on Day 1 (mean ± SD: 5 ± 2.2) and 12 sows on Day 3 (mean ± SD: 7.5 ± 3.8)). Altogether 125 standing-to-lying down events were analyzed on Day 1 and 135 on Day 3. As a result of technical difficulties it was not possible to analyze the grunting vocalization in 25 standing-to-lying down events.

All behavioural analyses were conducted by one trained observer (MM) who used the Observer software (The Observer, Version 8, Noldus Information Technology, Wageningen, Netherlands).

2.2.2. Analysis of piglet position

At the moment the sow began to lift a front foot and placed her knee on the floor, the number and the identity of piglets present in the danger zone, the number of piglets in the sow area and the number of piglets clustered were counted (see definitions in Table 1b). The same number of standing-to-lying down events per sow was analyzed as described under Section 2.2.1. The proportion of piglets which were present in the danger zone, sow area and clustered was calculated as the percentage of piglets in the litter.

2.2.3. Analysis of piglet condition and piglet mortality

In order not to disturb maternal behaviour during farrowing, piglet weight and rectal temperature were measured on Day 1 immediately after the farrowing was finished (mean ± SD: 3.2 ± 2.5 h after the birth of the first piglet). On Day 3 weight and rectal temperature measurements were taken at 48 h after the birth of the first piglet. In order to determine whether there was an effect of latency from the birth of the first piglet to rectal temperature measurements on piglet rectal temperature on Day 1 a PROC GENMOD test was run; rectal temperature was not significantly affected by the latency from the birth of the first piglet until the time of the measurement (Z = 1.83, NS). On Day 1, every piglet was marked (by marker pen) with a number on its back for identification on the video record. As piglet mortality was an important measure in this study, there was no human assistance provided to a piglet when it was crushed. However, to follow common practices of commercial pig farming and to avoid suffering the ethical decision was taken to humanely euthanize the piglets which were not able to survive because of body deformations, injuries and long-term starvation in large litters (N = 7). All instances of piglet

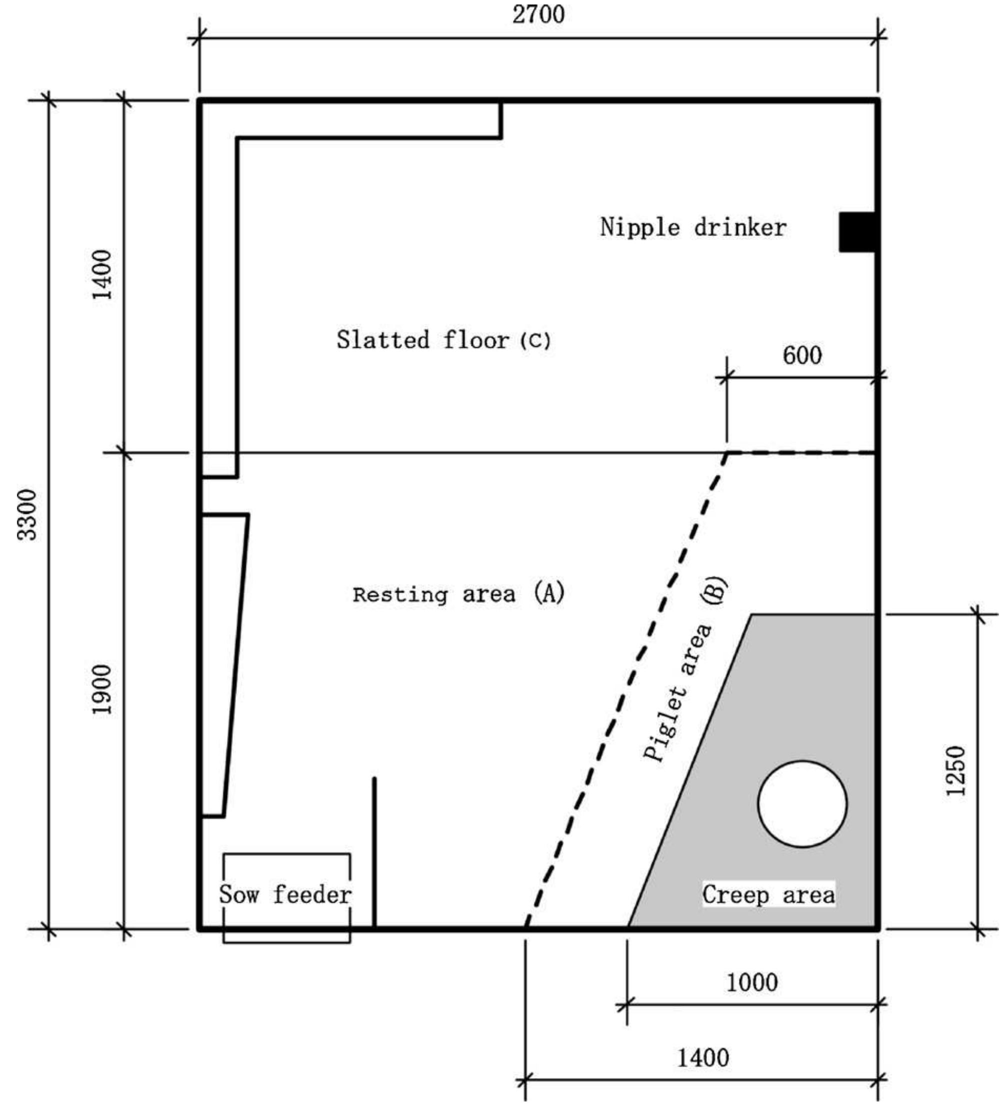

Fig. 1. The farrowing pen with resting area (A), piglet area including creep area (B) and slatted floor (C). All measures in mm.

Table 1a
Variables included in the analysis of standing-to-lying down events of the sow.

Variable	Definition
Sow vocalization	One grunt is one single sound separated by a silent period
Sniffing	Sow's snout is at a distance of less than 10 cm from the body of the piglet
Nudging	Sow moves piglet using her snout (physical contact)
Sow pre-lying communication in total	Sum of the frequency of sow vocalization, sniffing and nudging piglets
Start of pre-lying communication	Time when one of the behaviours (sow vocalization, sniffing or nudging) occurred for the first time within 2 min before the sow lay down (adapted from Pokorná et al., 2008)

Table 1b
Variables included in the analysis of piglet position.

Variable	Definition
Number of piglets in the danger zone	Number of piglets present in the area within one piglet length of the sow on the side on which she is about to lie down (Pokorná et al., 2008)
Number of piglets in the sow area	Number of piglets present in the resting area and slatted floor within approximately 1 m from the sow
Number of piglets clustered	Number of piglets present in the resting area and slatted floor which are within a distance of one piglet length from each other (for a minimum of 3 piglets)

mortality were noted and a macroscopic post-mortem examination was conducted to determine the cause of death. Causes of death were: stillborn (lungs sink in water on post-mortem examination), crushed (physical signs of crushing), or dead by starvation (malnourished and no milk in the stomach). The physical lesions of crushing included: bruising, lacerations, bone fractures, haemorrhages and/or injuries of internal organs. Evidence from video recordings also assisted with establishing accurate cause of death.

3. Statistical methods

For all statistical analysis, the individual sow was considered as an independent subject.

In cases when the dependent variable crushing was calculated, only one measurement for each sow was available, therefore a generalized linear regression model was used. In all other models, each sow had repeated observations and formed a cluster of observations. In this case, a marginal generalized regression models for clustered response were used. The predictors of TIME PERIOD, PARITY and LITTER SIZE were covariates in all models, unless otherwise stated. The predictor TIME PERIOD was a categorical variable with two levels (Day 1 and Day 3); the predictors PARITY and LITTER SIZE were included in the model as continuous variables. Only information about significant effects ($P < 0.05$) in the specific models is presented, unless otherwise stated.

The Poisson regression (when the mean of the data was nearly equal to its variance) and Negative binomial regression (when data were over-dispersed) were applied for modelling the frequency of pre-lying behaviour (sow vocalization, sniffing and nudging). These types of regressions were also used for modelling the proportion of piglets (calculated out of litter size) in the danger zone, in the sow area and clustered; this was done by considering the so called offset regressor which was the logarithm of litter size, unless stated otherwise. For brevity, we denote these proportions as "proportional states of piglets". Communication variables were tested separately with respect to crushing in the model. For generalized linear (or marginal) models the output presented (Z or χ^2), used for inferential purposes, depended on the number of observations in the sample. For small to moderate samples (50 observations and less), the χ^2 statistic was used, otherwise the Z statistic is presented (Agresti, 2007).

3.1. Association between sow pre-lying communication and the proportion of piglets in the danger zone, sow area and piglet clustering

The negative binomial regression (PROC GENMOD) was applied to test the effects of sow–piglet communication on the proportion of piglets present in the danger zone (first model), the proportion of piglets present in the sow area (second model) and the proportion of clustered piglets (third model) with predictors SNIFFING, SOW VOCALIZATION and NUDGING.

3.2. Association between sow pre-lying communication, piglet position and piglet clustering on the probability of crushing

The logistic regression (PROC GENMOD) was applied to test the effect of each component of sow per-lying communication separately for Day 1 and Day 3 on the probability of fatal crushing. Similarly, logistic regression was applied (PROC GENMOD) to test separately the effects of proportion of piglets in the danger zone (first model), the proportion of piglets in the sow area (second model) and of piglet clustering (third model) for each time period on probability of piglet crushing.

3.3. Frequency of sow pre-lying communication on Day 1 and Day 3

The Poisson regression model was applied (PROC GENMOD) to assess whether the frequency of sow vocalization, sniffing, nudging and sow pre-lying communication in total differed between Day 1 and Day 3.

3.4. Association between piglet condition and their presence in the danger zone before lying down of the sow and probability of crushing

The logistic regression was used to test the probability of piglet presence in the danger zone in relation to piglet weight and rectal temperature separately on Day 1 and on Day 3. The predictors PARITY, LITTER SIZE and TIME OF WEIGHT and TEMPERATURE MEASUREMENTS (latency from the birth of the first piglet and the measurements of piglet weight and rectal temperatures) were used as covariates.

The logistic regression (PROC GENMOD) was applied to test whether the probability of crushing was associated with the weights and rectal temperatures of crushed piglets separately on Day 1 and Day 3. The predictors PARITY, LITTER SIZE and TIME OF WEIGHT and TEMPERATURE MEASUREMENTS were used as covariates.

4. Results

4.1. Association between sow pre-lying communication and piglet presence in the danger zone, sow area and piglet clustering

At least one piglet was present in the danger zone on Day 1 in 52.8% of standing-to-lying events ($N = 66$ out of 125 events) and on Day 3 in 13.3% ($N = 18$ out of 135 events) at the moment when the sow started to lie down. The proportion of piglets present in the danger zone increased significantly when the frequency of vocalization ($P < 0.05$) and sniffing ($P < 0.05$) increased. On Day 1, there was a higher proportion of piglets present in the danger zone than on Day 3 ($P < 0.01$, 15.5% piglets on Day 1 vs. 5.8% piglets on Day 3). All effects are shown in Table 2.

The proportion of piglets in the sow area increased with increasing frequency of sniffing ($P < 0.05$). On Day 1, there was a higher proportion of piglets in the sow area than on Day 3 ($P < 0.0001$, Day 1: 82.8%; Day 3: 35.6% piglets).

Table 2
Effect of sow pre-lying communication (vocalization, sniffing and nudging) on piglet position and on piglet clustering (% of litter size). Variables of day effect, parity and litter size were included in the statistical model.

Variables	Piglets in danger zone (%)		Piglets in the sow area (%)		Piglets clustered (%)	
	Z	*P*-value	*Z*	*P*-value	*Z*	*P*-value
Vocalization	2.1	<0.05	0.17	NS	−0.34	NS
Sniffing	1.98	<0.05	2.41	<0.05	1.97	<0.05
Nudging	−0.96	NS	−0.51	NS	0.17	NS
Day effect[a]	2.93	<0.01	5.34	<0.0001	4.29	<0.0001
Parity	−1.07	NS	2.99	<0.01	2.62	<0.01
Litter size	0.86	NS	−1.07	NS	−1.15	NS

[a] Day effect: Day 1 and Day 3.

With increased parity, proportion of piglets in the sow area increased ($P < 0.01$).

The proportion of piglet clustering increased with increasing frequency of sniffing ($P < 0.05$). On Day 1 there was a higher proportion of piglets clustered than on Day 3 ($P < 0.0001$, Day 1: 70.1%; Day 3: 26%). With increased parity, proportion of piglets clustered increased ($P < 0.01$).

4.2. *Piglet crushing*

Over the three days post-partum, 14.4% of piglets (34 out of 236 live born piglets) died, 6.4% of piglets died as a result of crushing (14 piglets on Day 1, one piglet on Day 3). The probability of piglet crushing was not significantly affected by any component of the sow pre-lying communication (vocalization: $P = 0.67$, $\chi^2_{(1)} = 0.18$ on Day 1 and $P = 0.45$, $\chi^2_{(1)} = 0.57$ on Day 3; sniffing: $P = 0.11$, $\chi^2_{(1)} = 2.55$ on Day 1 and $P = 0.11$, $\chi^2_{(1)} = 2.5$ on Day 3; nudging: $P = 0.21$, $\chi^2_{(1)} = 1.61$ on Day 1 and $P = 0.3$, $\chi^2_{(1)} = 1.08$ on Day 3) nor by piglet position in the danger zone ($P = 0.27$, $\chi^2_{(1)} = 1.2$), sow area ($P = 0.24$, $\chi^2_{(1)} = 1.37$) or piglet clustering ($P = 0.25$, $\chi^2_{(1)} = 1.31$).

4.3. *The ontogeny of pre-lying communication*

On Day 1 compared to Day 3 there was a higher total number of pre-lying communications in total ($Z = 3.41$, $P < 0.0001$), a higher frequency of sow vocalization ($Z = 4.17$, $P < 0.0001$) and nudging tended to increase ($Z = 1.88$, $P < 0.1$, Fig. 2). Sniffing was not effected by the time period ($Z = -0.14$, NS). The frequency of sow vocalization decreased significantly with increased parity ($Z = -5.35$, $P < 0.0001$), but parity did not significantly affect sniffing, nudging or the pre-lying communication in total.

4.4. *Association between piglet condition and presence in the danger zone before lying down and probability of crushing*

Piglets with higher weight were more likely to be present in the danger zone on Day 1 ($Z = 4.79$; $P < 0.0001$) but rectal temperature on Day 1 ($Z = -0.07$, NS) and piglet weight ($Z = 0.4$, NS) and rectal temperature on Day 3 ($Z = -0.36$, NS) had no effect.

There was a significant effect of piglet weight on the probability of crushing ($Z = -2.05$, $p < 0.05$). With decreased weight, the probability of crushing increased on Day 1. No effect of rectal temperature on the probability of crushing on Day 1 was detected ($Z = -1.5$, NS). The low number of crushing events on Day 3 ($N = 1$) did not allow statistical analysis.

5. Discussion

To our knowledge this is the first study which focuses on the sow pre-lying communication including vocalization and its effect on piglet location at the moment when the sow starts to lie down. We confirmed our prediction only in one respect; that a higher pre-lying communication increased piglet clustering. However, contrary to our prediction, more communication initiated by the sow (i.e. vocalization, sniffing) was associated with a higher proportion of piglets in the danger zone and the sow area before lying down and, there was no effect of sow–piglet communication on the incidence of piglets being crushed. Furthermore, it was surprising that hypothermic piglets of lower weight were not present more in the danger zone; however piglets of lower weight were at a higher risk of crushing.

5.1. *Association between sow–piglet pre-lying communication and piglets' location and piglet clustering*

It has been suggested that sow pre-lying behaviour may help to reduce the risk of crushing by ensuring that piglets are awake and able to anticipate the forthcoming

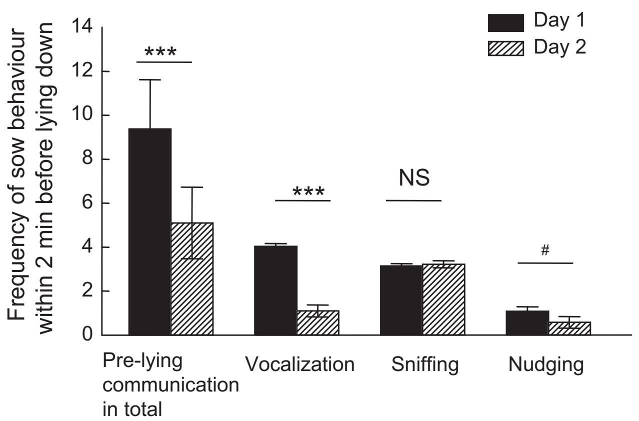

Fig. 2. Frequencies of sow pre-lying communication (mean ± S.E.) on Day 1 and Day 3 pp, ***$P < 0.0001$, #$P < 0.1$, NS: not significant.

lying down event (Damm et al., 2005), and move out of the danger zone (Blackshaw and Hagelso, 1990; Marchant et al., 2001). However, most of the cited studies focused on the pre-lying behaviour and the probability of crushing but did not study the relationship between pre-lying behaviour and piglet location except for one study (Pokorná et al., 2008). At first glance it was surprising to find that a higher frequency of sow pre-lying communication (vocalization and sniffing) increased the proportion of piglets in the danger zone. Our results indicate that more sow pre-lying communication attracted a higher proportion of the piglets close to the sow in the place with a higher risk of crushing (Blackshaw and Hagelso, 1990; Marchant et al., 2001). To some extent this confirmed results from the study conducted by Pokorná et al. (2008) in which more pre-lying behaviour, based on a scoring system, did not influence the probability that piglets would have moved out of the danger zone and from the sow area into the creep area during the first 24 h pp. The mentioned study (Pokorná et al., 2008) was conducted in modified farrowing crates and it was suggested that the restricted space made it almost impossible for the mother to lie down without having piglets in the danger zone. The present study, conducted in large loosed housed pens (7 m^2), rejected this explanation. However, our study supports recent findings that piglets are highly motivated to rest and stay near the sow and litter mates despite unfavourable thermal conditions in the sow area and the risk of crushing, instead of staying in thermal comfort in the creep area during the first days post partum (e.g. Andersen et al., 2007; Vasdal et al., 2009, 2010). Staying near the sow seems to be an adaptive behaviour of the piglets because the sow provides warmth, milk and protection (in outdoor environments) and they are also sorting out their teat order and teat fidelity (De Passillé et al., 1988). Therefore, contrary to our prediction, the area in very close proximity to the sow (i.e. the danger zone) might be perceived by neonatal piglets as the optimal place in the pen. The result that newborn piglets stay near the sow is not a new observation; in semi natural conditions piglets spend the first few days after birth in the nest in close contact with the sow (Jensen, 1986; Stangel and Jensen, 1991). It seems that this knowledge relating to the natural behaviour of newborn piglets, known for almost 20 years, has not been implemented as design criteria for farrowing pens and there have been unsuccessful approaches to increase the piglet use of the creep area by making it more attractive (e.g. Vasdal et al., 2010).

5.2. Association between sow pre-lying communication, piglet position and piglet clustering on the probability of piglet crushing

In our study the majority of piglet crushing occurred on Day 1 (93%) which confirms findings from previous studies (i.e. Marchant et al., 2001; Wischner et al., 2010). Similar to other studies which looked at the effect of different components of the pre-lying behaviour and piglet mortality (Špinka et al., 2000; Pokorná et al., 2008), we did not detect any association between the pre-lying communication and piglet crushing in the present paper. However, the number of crushing events was relatively small. In contrast, standing-to-lying events ending by piglet crushing were more frequent when sows performed none or very little pre-lying behaviour (Marchant et al., 2001), and performed less rooting on Day 3 (Valros et al., 2003). These contradictory results might be due to slightly different approaches and methods used.

How dangerous is piglet presence in the danger zone? In the present study on Day 1 there was at least one piglet present in the danger zone in more than 50% of all sow lying down events and around 10% of all events on Day 3. On Day 1, the number of events when fatal crushing occurred during lying was more than 4.5 times lower than the number of events when at least one piglet was present in the danger zone (66 standing-to-lying down events with at least one piglet present in the danger zone and 14 piglets crushed). Furthermore, our results showed that there was no effect of the proportion of piglets in the danger zone on piglet crushing. When a piglet gets trapped it starts screaming immediately. Weary et al. (1996) showed that piglets which are trapped under the sow for less than 1 min generally survive. Thus, staying close to the mother within the first few days post partum might increase the risk of maternal crushing (Weary et al., 1996; Marchant et al., 2001) but crushing may not be fatal and the benefits of heat provision, milk and protection against predators (in an outdoor environment) might be greater than the risks. Apparently, there is a trade-off between the costs and benefits which the closeness of the mother represents for piglets. Traditionally it has been assumed that sow's maternal crushing is an involuntary accident related to inadequate design of the farrowing environment. However, recent studies have suggested that fatal crushing may also be an alternative way of reducing maternal investment, especially in large litters (Drake et al., 2008; Andersen et al., 2005, 2011). Brood reduction is energetically more efficient shortly after birth. Significant neonatal mortality may actually improve a sow's overall fitness by enabling her to invest more resources in her remaining young while maintaining her own body condition (Drake et al., 2008). Despite relatively large litter sizes (mean ± SD: 13 ± 2.9) in the present study no effect of litter size on piglet crushing was found, which can be explained by the stockperson husbandry skills on the farm, including cross-fostering. This study aimed to investigate communication of the sow towards piglets in relation to standing-to-lying posture changes, further studies should focus on sow–piglet communication in general.

5.3. Ontogeny of the sow pre-lying communication

In the present study the frequency of pre-lying communication (sow pre-lying communication in total, vocalization and nudging) was higher on Day 1 compared to Day 3 when the piglets are most vulnerable and the risk of crushing is greatest (Weary et al., 1996; Marchant et al., 2001). The same ontogeny effect was found by Marchant et al. (2001) and Blackshaw and Hagelso (1990) for different components of pre-lying behaviour. The question arises how important are the specific components of pre-lying communication. Sniffing and sow vocalization do not exclusively occur before lying down but they have been observed during and after birth of piglets and before and after nursing (Whatson and Bertram, 1982–1983; Jensen, 1988; Jarvis et al., 1999; Illmann et al., 2001; Pedersen et al., 2003). Harris and Gonyou (1998) reported "sniffing" as a common behaviour between the sow and piglets in non-confined conditions. One function of sniffing, and as well of sow grunting before lying down, might be to wake up piglets (Damm et al., 2005) or enable them to find the udder after parturition. Grunting vocalization of the sow is an important feature to announce nursing and very short milk ejection in pigs (Illmann et al., 2001). However, another function of sow pre-lying communication might be solely to support development of the olfactorial (Maletínská et al., 2002) as well as acoustical mother–young bond. Grunting of the mother is important for piglets in order to find her in case of losing contact, specifically the first hours after birth. It is known that piglets are able to recognize the grunting vocalization from their own mother against alien sows 36 h post partum (Horrell and Hodgson, 1992). Given the low frequency of nudging behaviour displayed by the sow in this study, it is questionable whether it plays an important role in sow–piglet communication (see Fig. 2). To sum up, sow behaviour vocalization and sniffing piglets might be a common behaviour of the sow towards piglets in order to strengthen the bond between the mother and her offspring which starts to develop immediately after the birth and is fundamental for piglet survival.

5.4. Association between piglet condition and presence in the danger zone before lying down and the probability of crushing

Contrary to our prediction that on Day 1 heavier piglets were more likely to be present in the danger zone and there was no association between rectal temperature and piglet presence in the danger zone detected on both days. Our results suggest that the benefit of staying close to the mother in terms of increased survival probability (i.e. more milk, heat) is larger than the risk of getting crushed. Piglets in good body condition (heavy, vital ones) can afford the risk of staying close to the sow in order to maintain the best position at the udder and get a higher colostrum intake (De Passillé et al., 1988) compared to weak piglets (light ones) that are more likely to get crushed (Svendsen et al., 1986; Dyck and Swierstra, 1987). To our knowledge there is only one study which analyzed piglet weight gain and time spent in the risky area during standing and sitting (Weary et al., 1996). It was demonstrated that piglets gaining less weight spent more time in the risky area, but these authors did not report whether there was a higher incidence of crushing among the starved piglets compared to the heavy ones. The body condition of the piglets might be a good indicator of how the piglets move around the sow, and the light piglets are quite often observed close to the sow when the rest of the litter is not present. With decreased piglet weight measured on Day 1 the probability of crushing increased, which corresponds with the findings of several studies on the effects of neonatal piglet weight on their survival (e.g. Dyck and Swierstra, 1987; Tuchscherer et al., 2000; Milligan et al., 2002; Vasdal et al., 2010). The motivation of piglets to spend the first few days after farrowing in contact with the mother is very high, regardless of the comfort and softness in the creep area (Vasdal et al., 2010), heat lamp location and air temperature (Hrupka et al., 1998). It can therefore be considered as a battle against biology to aim at attracting newborn piglets away from the sow (Vasdal et al., 2010).

In conclusion, our study shows that more sow pre-lying communication attracted piglets to the sow and even increased the proportion of piglets in the predefined danger zone before lying down. However, there was no association detected between pre-lying communication and piglet location on the incidence of piglet crushing. Close proximity of piglets to the sow during the first days post partum outside the time of nursing seems likely to stimulate the mother–piglet bonding process. The benefits of staying close to the udder in terms of milk, heat and comfort appears to be much larger than the risk of getting crushed by the mother, especially for piglets in a good condition.

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Ustájení prasnic během laktace: welfare prasnic a mortalita selat

M. MELIŠOVÁ, G. ILLMANNOVÁ, H. CHALOUPKOVÁ
Výzkumný ústav živočišné výroby v. v. i., Praha-Uhříněves

SOUHRN

Melišová M., Illmannová G., Chaloupková H. **Ustájení prasnic během laktace: welfare prasnic a mortalita selat.** Veterinářství 2012;62:417-419.

V poslední době se zvyšuje zájem o welfare kojících prasnic a selat z pohledu ustájení. Řada studií potvrdila, že porodní klece způsobují utrpení kojících prasnic, a tím pádem mají negativní dopad na úroveň jejich welfare. Některé evropské země již legislativně chov kojících prasnic v porodních klecích zakázali (Švédsko, Švýcarsko a Norsko), některé země prochází přípravou na jejich omezení (Rakousko). V ekologickém zemědělství legislativa Evropské unie chov kojících prasnic v klecích vylučuje. Lze proto předpokládat, že i u konvenčních chovů se tato problematika bude postupně řešit na úrovni celé Evropské unie. Příspěvek uvádí přehled studií, které porovnávají vliv ustájení prasnic během laktace v porodních klecích a ve volném ustájení na jejich mateřské chování a mortalitu selat. Zaměřuje se na oblasti, které jsou považovány za klíčové z hlediska zabezpečení dobré životní pohody prasnic. Současně zaměřuje pozornost na hlavní faktory, které ovlivňují mortalitu selat.

SUMMARY

Melišová M., Illmannová G., Chaloupková H. **Housing of lactating sows: welfare of sows and mortality of piglets.** Veterinářství 2012;62:417-419.

There is a recent increase of interest in welfare of lactating sows and piglets in terms of housing system. Several studies have confirmed that the farrowing cages cause suffering of lactating sows, and thus have a negative impact on their welfare. Some countries in Europe have already banned housing of lactating sows in the farrowing crates (Sweden, Switzerland and Norway) and some countries are currently in the process of its limitation (Austria). In organic farming, rearing of lactating sows in the farrowing cages is not compatible with European Union legislation. It is therefore possible to assume that this issue will be soon addressed also for crated sows at the European Union level. The paper presents an overview of important studies that compare the influence of housing system (farrowing crates and loose-housing) in lactating sows on their maternal behavior and piglet mortality and focuses on areas that are considered essential to the good welfare of sows and also addresses important factors that affect piglet mortality.

Úvod

Produkce zdravých životaschopných selat je základní podmínkou prosperujícího chovu prasat. Vysoká mortalita selat po porodu pohybující se mezi 10–30 %[1] představuje v chovech prasat, v celosvětovém měřítku, stále vážný ekonomický problém. Vedle ekonomického problému se jedná o závažný problém welfare, který bývá často opomíjen. Jedním z důvodů zavedení porodních klecí do praxe bylo snížení ztrát z důvodu zalehnutí selat prasnicí. Nicméně v posledních letech bylo v porovnávacích studiích zjištěno, že celková mortalita selat v porodních klecích a ve volném ustájení je shodná, liší se pouze příčiny úhynu selat.[2,3] Na druhé straně někteří autoři došli k závěru, že ustájení v porodních klecích má negativní dopad na úroveň welfare prasnic, protože porodní klec neumožňuje prasnici volný pohyb, stavbu hnízda a komunikaci se selaty po porodu.[3,4]

Význam stavby hnízda na welfare prasnic a produkci selat

Ve volné přírodě se prasnice 1–2 dny před porodem vzdálí od ostatních prasnic a vyhledá chráněné místo, kde pomocí materiálu, který má na místě k dispozici (tráva, větve, kapradiny aj.) postaví pro selata hnízdo.[5] Toto chování nebylo domestikací změněno,[5,6] a proto i prasnice, ustájené v klecích nebo volných kotcích, vykazují v průběhu 48 hod. před porodem zvýšenou míru lokomoce[7] a asi 12 hod. před porodem si staví hnízdo.[8] Pokud prasnice nemají k dispozici vhodný materiál pro stavbu hnízda, lze u nich pozorovat chování, které můžeme nazvat stavění hnízda na prázdno.[9] Absence stavebního materiálu měla za následek prodloužení porodu, vyšší počet mrtvě narozených selat a celkové mortality, stereotypní chování, vyšší hladiny stresového hormonu kortizolu a vyšší frekvenci pulzu srdce ve srovnání s prasnicemi, které stavební materiál k dispozici před porodem měly.[10,11] Některé studie zkoumaly, který materiál je více či méně vhodný pro stavbu hnízda. Bylo prokázáno, že i piliny lze využít jako vhodný materiál, který naplní potřebu prasnic stavět hnízdo bez negativních následků pro prasnici či selata, ačkoliv s pilinami má prasnice omezenou možnost manipulace (nelze z nich vystavět funkční hnízdo). Piliny lze tak použít jako vhodný materiál tam, kde užití slámy není možné z technických důvodů.[12]

Ve volnosti hnízdo slouží selatům jako ochrana před chladem, navíc měkké podloží hnízda chrání selata před možným zalehnutím. Také v chovech domácích prasat je nutné, aby podestýlka simulující hnízdo sloužila jako termoregulační ochrana selat po narození, protože novorozená selata se drží prvních 24 hodin v blízkosti matky a teprve později začnou využívat prostor určený pro selata s výhřevnou lampou nebo podložkou.[13]

Otázku dispozice materiálu na stavbu hnízda před porodem ošetřuje Směrnice 2001/93/EC, která uvádí: V týdnu před očekávaným porodem musí prasnice a prasničky dostat v dostatečném množství vhodný podestýlkový materiál, pokud to umožňuje systém odstraňování tuhých a tekutých výkalů používaných v zařízení. Bylo nicméně zjištěno, že pokud jsou porodní klece částečně nebo plně zaroštované, pak podestýlka není v praxi prasnicím běžně poskytována.[14] Prasnice v klecích tak nemohou plně uspokojit silnou motivaci stavět hnízdo, a to nejen kvůli nedostatku prostoru, ale i materiálu. Ve volném ustájení, kde má prasnice k dispozici větší prostor, se lze vyvarovat zacpání roštů podestýlkou rozdělením porodního kotce na dvě části, tj. jednu část ponechat celoroštovou a bez podestýlky (prasnice zde kálí a v případě potřeby se může ochladit), druhou část s pevnou podlahou a s podestýlkou (pro stavbu hnízda a odpočinek). Tyto dvě oblasti mohou být odděleny nejen opticky, ale i přímo nízkou přepážkou, která zcela zamezí přístupu podestýlky na rošty, nicméně prasnice ji může bez problému překročit (tento design volného ustájení je v současné době testován v Norsku).

Chování prasnic při uléhání – riziko pro selata?

Jednou z hlavních obav chovatelů z volného ustájení je mateřské chování související se zalehváváním selat vlastní matkou, které je považováno za hlavní příčinu úhynu selat.[2] Nejčastěji k zalehávání selat dochází v průběhu prvních dvou dnů po porodu v situacích, kdy prasnice mění polohu.[15] V případě, že prasnice má dostatek volného prostoru, provádí před ulehnutím charakteristické tzv. předlehací chování.[16] Předlehací chování (rytí, hrabání přední končetinou, očichávání selat a chrochtání) by mohlo fungovat jako signál selatům dostat se včas z dosahu těla prasnice.[17] Nicméně nová studie autorů Melišová a kol. (2011) ukázala, že vyšší frekvence předlehacího chování způsobila naopak přiblížení selat k prasnici, avšak blízkost selat u prasnice nesouvisela s mírou zalehnutí. Prasnice při uléhání nejprve pokrčí přední končetiny v zápěstních kloubech, několik sekund setrvá v této pozici a teprve potom pomalu sesune zbytek těla na zem.[18] Z tohoto důvodu je nezbytné, aby prasnice měla zdravý pohybový aparát.

V případě, že dojde k přilehnutí nebo přišlápnutí selete, sele začne okamžitě výrazně vokalizovat a matka na tyto vysokofrekvenční zvuky reaguje, a to bez rozdílu na použitou technologii ustájení[19]. Pokud prasnice zareaguje a změní polohu do zhruba jedné minuty, sele přežije.[20] S prodloužením času reakce prasnice se snižuje pravděpodobnost přežití selete.

Ustájení a mortalita selat

Rozsáhlé studie porovnávaly mortalitu selat v porodních klecích a volných porodních kotcích o velikosti alespoň 5 m^2 na 860 švýcarských farmách[3] a na 112 farmách ve Velké Británii.[2] Obě studie dospěly k závěru, že ve volném ustájení je sice mírně vyšší pravděpodobnost zalehnutí selat prasnicí, nicméně úhyn selat, způsobený jinými příčinami než zalehnutím (vyhladověním, nemocemi aj.), je naopak vyšší v klecovém ustájení. Konkrétně u švýcarských farem byla celková mortalita selat na vrh v porodní kleci 1,42 a ve volném porodním kotci 1,40 selete. U britských farem jsou údaje uváděny v procentech: celková mortalita v porodní kleci byla 11,7 %, ve volném ustájení 10,9 %. Procento zalehlých selat v porodní kleci 4,6 % versus volný porodní kotec 6 % a procento úhynu způsobeného jinými příčinami v porodní kleci 6,7 % versus volný porodní kotec 4,4 %.

Ve stejné studii byla také testována kombinace obou způsobů ustájení – prasnice byla před, během a prvních dnů po porodu ustájena v porodní kleci a po zbytek laktace byla ustájena volně (tuto kombinaci ustájení používá 33 % farem ve Velké Británii; je povolen u problémových prasnic ve Švédsku, Švýcarsku a Norsku). U kombinovaného ustájení byla mortalita selat nejvyšší druhý a třetí den po porodu. Skutečnost, že u klecového a volného ustájení byla mortalita nejvyšší první den, naznačuje, že kombinované ustájení jen časově úhyn selat oddálilo.[2] Existuje zde totiž řada významných faktorů, které určují mortalitu selat. Jednak selata o nízké porodní váze jsou zalehnuta s větší pravděpodobností,[16] přičemž post-mortem analýzy ukazují, že většina zalehnutých selat nemá v žaludku mléko, což je zřejmě zapříčiněno jejich neúspěchem v bojích o struky se svými sourozenci. Tato vyhladovělá selata jsou pravděpodobně ve volném ustájení zalehnuta prasnicí krátce po porodu, v porodní kleci uhynou následkem vyhladovění až později.[3] Je také známo, že kondice selat je silně ovlivněna velikostí vrhu, se zvyšující se velikostí vrhu dochází i ke zvýšení mortality selat.[2] Snížením selekčního tlaku na šlechtění prasnic za účelem dosažení co nejvyššího možného počtu selat ve vrhu by bylo možno dosáhnout snížení mortality selat, což by vedlo ke zlepšení úrovně welfare selat, neboť selata před uhynutím prožívají pocity bolesti a utrpení.

Dalším významným faktorem, určujícím pravděpodobnost

Volné ustájení Norsko (foto Michala Melišová)

mortality, je tělesná teplota po narození. Novorozená selata nemají zcela vyvinutou termoregulaci, a proto je extrémně důležité, aby se napila mléka ihned po porodu. Podchlazené sele má menší šanci nalézt struk a koordinovat své pohyby, a právě nízká porodní hmotnost a nízká tělesná teplota dvě hodiny po porodu je rozhodující pro schopnost selete vyhnout se zalehnutí prasnicí či úhynu, způsobeného vyhladověním nebo zraněním, a to bez rozdílu vlivu technologie ustájení. Lze tedy shrnout, že s nižší tělesnou hmotností a teplotou stoupá pravděpodobnost, že sele uhyne.[21]

Agresivita prasnic vůči selatům a ošetřovateli

U prasnic po porodu se bez rozdílu v použité technologii ustájení může objevit agresivní chování jak vůči selatům, tak i ošetřovateli. Útočné chování prasnice vůči selatům se objevuje zejména u prvorodiček. Příčiny tohoto chování nejsou příliš jasné, jeho výskyt je nízký (5–8 % prasnic) a pravděpodobně jedním z důvodů tohoto chování je stres a úzkost prasnice z novorozených selat. V přirozeném prostředí se prasnice se selaty asi po dvoutýdenní izolaci v období porodu vrací k původní skupině prasnic, kde se prasničky mají možnost setkat se selaty, aniž by samy rodily, což kontrastuje se situací ve většině konvenčních chovů. Agrese prasnice vůči ošetřovatelům vychází zřejmě ze zvýšené mateřské obranné reakce po porodu. Bylo zjištěno, že tato agrese je konzistentní, tj. opakuje se i v rozpětí několika laktací za sebou. Ve volném ustájení, kde by s případnou agresivitou prasnice mohl vzniknout problém, je proto vhodné vyřadit agresivní prasnice po první laktaci z chovu.[22]

Ekonomika chovu

Volné ustájení musí být konkurenceschopné i z hlediska rentability chovu, která je rozhodující pro chovatele a promítne se v cenách finálního produktu, bohužel ale existuje velmi málo srovnávacích studií zaměřených na ekonomiku chovu. Ve studii provedené ve Velké Británii[23] bylo zjištěno, že celkové náklady na jednu prasnici ve volném ustájení (zahrnující náklady na design ustájení, materiál, stavbu ustájení, veškeré vybavení ustájení, jako jsou podlahy, napáječky atd. a veškeré provozní náklady) jsou o 17 % vyšší než v klecovém ustájení. Počet pracovních hodin ošetřovatele na prasnici a rok byl v obou ustájeních srovnatelný (volné ustájení: 7 hod./prasnice/rok, klecové ustájení: 7,2 hod./prasnice/rok). Je nutné ale zdůraznit, že do této kalkulace nejsou zahrnuty všechny aspekty volného ustájení, jako je pozitivní vliv na zdraví a potažmo dlouhověkost prasnic, stejně tak na zdraví a přírůstky selat a kvalitu masa po porážce.[24]

Závěr

Prasnice ustájené v porodních klecích nemají možnost projevit své přirozené chování, a to jak v době před porodem, tak i po porodu, což má silný negativní vliv na její welfare. Volné ustájení je z hlediska hodnocení mortality selat s klecovým ustájením srovnatelné, ovšem díky většímu životnímu prostoru umožňuje prasnici uspokojit řadu jejích základních etologických potřeb spojených s porodem a péčí o potomstvo. Dále také dovoluje prasnici více fyzického pohybu, což má pozitivní vliv na její zdravotní stav. Pro správné využití volného ustájení uvádíme tato doporučení:

Porodní kotec by měl být vystlaný podestýlkou (sláma, piliny aj.) pro stavbu hnízda a termoregulaci novorozených selat.

Prasnici by měl být poskytnut dostatečný prostor na otáčení a možnost provádět předlehací chování.

Chovatel by měl vybrat pro chov matky s dobrým mateřským chováním, tj. zdravé, které mohou správně vstávat a uléhat a nejsou agresivní vůči ošetřovateli.

Je třeba kontrolovat kondici selat po narození (přikládat selata ke strukům aj.).

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Adresa autora:
Ing. Michala Melišová
Výzkumný ústav živočišné výroby
Přátelství 815
104 00 Praha-Uhříněves
melisova.michala@vuzv.cz