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Effect of temporary crating on maternal behaviour and piglet mortality

Master´s thesis

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Declaration

I hereby declare that I have authored this master's thesis carrying the name "Effect of temporary crating on maternal behaviour and piglet mortality" independently under the guidance of my supervisor. Furthermore, I confirm that I have used only professional literature and other information sources that have been indicated in the thesis and listed in the bibliography at the end of the thesis. As the author of the master's thesis, I further state that I have not infringed the copyrights of third parties in connection with its creation.

In Prague on the 12th of April 2023 _____

Acknowledgments

I would like to acknowledge RNDr. Gudrun Illmann, CSc. for showing me the beauty of maternal behaviour of sows and for the guidance during the working process of my master's thesis and Ing. Veronika Sekyrová for thorough explanation of video analysis. Furthermore, I would like to acknowledge prof. Mgr. Ondřej Slavík, PhD. for his inspiring enthusiasm for ethology; prof. MVDr. Jana Kottferová, PhD. from University of Veterinary Medicine and Pharmacy in Košice for opening me the door into the world of ethology in the first place; my family and close friends who always supported me and, last but not least, my dogs Mulan and Ajsha, my life companions and great teachers, who have showed me my life path.

Effect of temporary crating on maternal behaviour and piglet mortality

Summary:

Temporary crating is an alternative housing system for lactating sows and their piglets that was created in order to improve sows' welfare. Sows in temporary crating are confined only for a short time interval (since the end of gestation period until approximately first 3 days post-partum) to minimise piglet mortality during this critical period. It is not clear whether there is a change in maternal behaviour of sows after crate opening. Specifically, whether there is a higher incidence of piglet trapping events during the performance of sow's postural changes after crate opening. The aim of this diploma thesis was to compare temporary crating system and permanent crating system with the focus on how the opening of a hinge farrowing crate affects sow's postural changes which could create life threatening situations for the piglets and potentially increase piglet mortality. Moreover, piglet trapping events, piglet vocalisation during these events and subsequent sow's responsiveness toward these piglet crush calls as a part of sow maternal behaviour repertoire were studied to bring more results which could, hopefully, persuade farmers into implementation of this type of housing in pig husbandry. Temporarily crated sows (n = 8) were crated since the end of their gestation period until day 4 post-partum. Behaviour of these sows was recorder over a 24 h period, both preceding and following the opening of a hinge farrowing crate, creating a 48 h long continuous recording. Permanently crated sows (n = 7) were crated since the end of gestation until weaning of their piglets. Behaviour of permanently crated sows was recorder over a 48 h period, starting on day 3 and ending on day 5 post-partum. The following behaviour was analysed 24 h after crate opening in both housing systems: the number of sow's postural changes such as standing up, lying down (duration, the use of pen support, piglets in danger zone), rolling behaviour and piglet trapping events (sow's reaction towards piglet vocalisation after trapping event). All data were analysed using SAS. Temporarily crated sows performed more postural changes such as standing-to-lying, sitting-to-lying, and rolling compared to permanently crated sows 24 h after crate opening. Temporarily crated sows used the slope wall less frequently once the crate was opened compared to permanently crated sows, however, they still preferred some kind of support, such as rails, while lying down. Increased number of postural changes did not increase the occurrence of trapping events. Results of our experiment show that opening of a farrowing crate significantly affects sows' behaviour but does not threaten the safety of piglets, in fact, temporary crating might have a positive effect on the welfare of sows and their piglets.

Keywords: pig, sow, piglet, temporary crating, pen, maternal behaviour, postural change, trapping, mortality, vocalisation, welfare

Content

1 Introduction

The domestication of pigs occurred between 8500 to 8000 BC (Caliebe et al. 2017) and although the natural behaviour of domestic pigs (*Sus scrofa domesticus*) is still very similar to their wild relatives – wild boar (*Sus scrofa*), animal husbandry has throughout the evolution of mankind undergone many changes.

The most drastic changes were implemented into pig husbandry in 1960s, when with the aim of space requirements reduction, maximisation of profit thanks to better production performance, decrease in labour required to maintain hygiene and reduction of piglet mortality, conventional crating system of sows was introduced (Edwards & Fraser 1997; Baxter et al. 2011; Goumon et al. 2022). In this type of housing system, sows are crated since farrowing and throughout lactation, unable to move and perform their natural repertoire of behaviour (Baxter et al. 2011). Although this type of housing is still very popular among farmers, it is connected to considerable amount of welfare issues.

A new alternative to the conventional permanent crating of sows could be the temporary crating system, in which sows are confined only during a short period of time, usually few days before farrowing until approximately the third day post-partum, and afterwards are given the opportunity to move freely in the pen area (Goumon et al. 2022). This new type of housing system takes into consideration the natural behaviour of sows and tries to implement the change in pig husbandry for the improvement of sows' as well as piglets' welfare and moreover, it tries to meet the requirements of farmers (Goumon et al. 2018). As a result, this type of housing system might represent a compromise between the needs and goals of farmers and the needs and welfare of sows and their piglets.

However, farmers are still hesitant, mostly due to the fear of lower piglet weight gain and high piglet mortality which could be caused by an increase in crushing events once the sow can move freely in the pen. Although several papers have studied this area, many results are contradictory and therefore, there is still a need for further research.

This diploma thesis therefore compares the temporary crating system and the permanent crating system with the focus on how the crate opening affects sow's postural changes which could create life threatening situations for the piglets and potentially increase piglet mortality. Moreover, piglet trapping events, piglet vocalisation during these events and subsequent sow responsiveness toward these piglet crush calls as a part of sow maternal behaviour repertoire will be studied to bring more results which could, hopefully, persuade farmers into implementation of this type of housing in pig husbandry.

2 Scientific hypotheses and aims of the thesis

The aim of this diploma thesis is to compare two different housing systems, specifically the permanent crating system with the temporary crating system 24 hour after crate opening, and their effect on the number of sows' postural changes, piglet trapping events and sows' reaction to piglet vocalisation during a trapping event.

The following hypotheses will be studied:

H1a: Sows in temporary crating perform more postural changes after crate opening than permanently crated sows.
H1b: Higher number of postural changes in temporary crating after crate opening might cause more piglet trapping events.

H2: Sow's reaction to piglet vocalisation will be faster in temporary crating after crate opening thanks to better mobility in the pen area.

H3a: Temporarily crated sows use the slope wall less often during lying down 24 hours after crate opening than permanently crated sows.
H3b: The decrease in the use of slope wall in temporarily crated sows 24 hours after crate opening is compensated by the increased use of other pen support during lying down.

H4: Temporarily crated sows are after crate opening more likely to lie down near the nest with a higher percentage of piglets in the nest.

H5: The proportion of fatal trapping events in both housing systems will not significantly differ.

3 Literature research

3.1 Maternal behaviour of sows

Wild boars (*Sus scrofa*) are very intelligent and secretive animals and in natural conditions create small sounders that are usually formed from several sows and their young offspring, creating so called family groups (Poteaux et al. 2009; Allwin et al. 2016) with single males living in the periphery (Jensen 1986). Domesticated pigs (*Sus scrofa domestica*) released into semi-natural conditions reorganise themselves into small groups and express typical rooting and foraging behaviour (Jensen 1986; Gabor et al. 1999) as their wild relatives. Moreover, not even maternal behaviour was significantly altered by domestication process (Gustafsson et al. 1999; Špinka et al. 2000; Wischner et al. 2009), and therefore we can see many parallels between behaviour performed by domestic sows (*Sus scrofa domestica*) and their wild counterparts (*Sus scrofa*) (Allwin et al. 2016).

Picture 1 Sounder of wisayan warty pig (*Sus cebifrons*) in semi-natural conditions in ZOO Bratislava (Simanová 2018).

3.1.1 Nest-building behaviour

The pre-partum period of sows belonging to the Suidae family is characterised by the construction of a farrowing nest. Approximately 15 to 24 hours prior to farrowing the sow separates herself from the herd and in order to find a suitable farrowing place, sow can walk between 2.5 to 6.5 km. The wandering and investigation are followed by the initial phase of nest-building behaviour during which the sow builds a 1.5 m long, 0.5 m wide and 10 - 15 cm deep nest (Jensen 1986). Controlled by internal factors, the initial phase consists of nosing, rooting, and pawing the soil. The subsequent phase of nest building and its arrangement is affected by external factors such as protection from adverse weather conditions (Jensen 1988; Wischner et al. 2009). The material for nest-building consists mostly of grass, marsh grass and other soft materials (Hanson & Karstad 1959; Jensen & Recén 1989) and can be carried from the distance of 6 to 10 m (Hanson & Karstad 1959).

As mentioned above, nest-building behaviour is affected by hormones. According to Castrén et al. (1993), it is the increase of prolactin concentration that initiates the nest

building behaviour, and the subsequent increased level of oxytocin ends the performance of this behaviour.

Picture 2 Sow carrying material for nest-building (Simanová 2022).

3.1.2 Parturition and nursing

The parturition in sows takes place after 115 days of gestation, but gestation time may vary between breeds and individuals with the actual time frame ranging from 105 days to 125 days (Sasaki & Koketsu 2007). In 1966, the average observed parturition time was 2.53 h (Jones 1966), however, nowadays the average time of farrowing increased to 3.58 h (Hoai Nam & Sukon 2020) due to the increased litter size (Walls et al. 2022). Besides the litter size it is also the number of stillborn and mummified piglets that greatly affects the length of parturition (Hoai Nam & Sukon 2020), with stillborn piglets having increased birth time interval compared to liveborn piglets (Van Dijk et al. 2005).

Right after the piglet is born the intake of immunoglobulin rich colostrum (Klobasa et al. 1987) and subsequently milk is required for its survival. Piglets immediately move to the udder, and it takes approximately 10 to 80 minutes until their first suckle (Bunger 1985; Damm et al. 2002; Pedersen et al. 2003). The "teat order" or the preference of a certain teat or a pair of teats is gradually formed during the post-partum period and nursing from the preferred teat becomes more stable as the piglets age (McBride 1963; Hemsworth et al. 1976; De Passillé et al. 1988; Mason et al. 2003). According to Skok and Škorjanc (2013) the teat order stability increased after the first week post-partum and remained at the same level during lactation with the highest stability at the anterior and posterior pair of teats, because these teats are most easily defended. Furthermore, piglets reflect sow's postural change and always remain at the same teat relative to their mother's head or tail (Skok & Škorjanc 2014).

Lying down with exposed udder, sow initiates nursing with slow grunts which triggers jostling for position between piglets and subsequent nursing phases: pre-massage which consist of nosing the udder and slow sucking; milk let-down characterised by sucking with

rapid mouth movement; and post-ejection massage recognised by the return to slow sucking, nosing and eventually leaving the udder or falling asleep near the sow (Whittemore & Fraser 1974; Fraser 1980).

The pre-massage effects the release of oxytocin which then starts approximately 10 – 20s long period of milk flow (Fraser 1980). To provide piglets with required amount of milk, nursing is repeated every 40 – 60 minutes (Hartmann et al. 1997). However, up to 30% of nursings do not result in milk let-down (Newberry & Wood-Gush 1985, Illmann & Madlafousek 1995). During these non-nutritive nursings, udder exposition and rhythmical grunting of sow is followed by piglet pre-massage behaviour, but sow's grunting does not increase, piglets do not display the rapid mouth movement and they do not receive any milk (Illmann & Madlafousek 1995; Illmann et al. 1999).

The post-ejection massage observed after the milk ingestion was because of its aspects compared to the honest begging in birds (Jensen et al. 1998) and it has been suggested that the massage of a certain teat could stimulate its future milk production (Algers & Jensen 1991; Špinka & Algers 1995; Jensen et al. 1998). This hypothesis was validated by results of King et al. (1997) and Skok and Škorjanc (2013) who confirmed that milk production is indeed affected by the demand of piglets and the intensity of mammary gland stimulation and as a result, bigger and heavier piglets have higher milk intake during lactation period (Skok & Škorjanc 2013).

3.1.3 Sow – piglet communication

The communication between sow and her piglets is an important component of bonding and is manifested through nasal contact (sniffing, nudging) and grunting (Jensen & Redbo 1987) which is often used to gather piglets for the upcoming nursing (Grimberg-Henrici et al. 2017). During the first days post-partum, piglets tend to stay in the proximity to their mother because of benefits such as source of milk, heat and protection (Melišová et al. 2011). This need for closeness can create potentially high-risk situations of being crushed by their mother while lying down or during the performance of other postural changes. Interestingly, sow communication with piglets can prevent piglet mortality as stated in Ocepek and Andersen (2018) and the performance of piglet directed pre-lying behaviour could prevent piglet crushing since as seen in Marchant et al. (2001), dangerous events connected with lying down behaviour were seen during occasions, in which no pre-lying behaviour was present.

The pre-lying behaviour can be classified as a form of mother-piglet communication which should alert the piglets and inform them about sow's upcoming postural change. During the pre-lying behaviour, sows manifest sniffing, looking around and nosing (Wischner et al. 2010), making eye contact with the piglets, rooting, or pawing the floor (Marchant et al. 2001; Valros et al. 2003) and then descent vertically or laterally (Blackshaw & Hagelso 1990; Marchant et al. 2001).

A significant increase in sow aggressive behaviour was seen during the post-partum lactation period and slightly more aggressive maternal behaviour was observed in connection to suckling (Jensen 1988). Moreover, gilts are more likely to perform aggressive behaviour

towards their offspring than sows that had litters in the past. This aggressive behaviour, known as savaging, can be observed as a deliberate attack on a piglet e.g., by biting, resulting in piglet's death (Marchant-Forde 2002; Chen et al. 2008). However, as suggested by Chen et al. (2008) this behaviour may not be explicitly piglet directed and it is possible that it is a part of other behavioural pathology.

3.1.4 Postural changes

In the initial farrowing period, sows are more active, perform more postural changes and investigate their piglets, but the occurrence of this behaviour and their activity subsequently decreases (Jarvis et al. 1999; Thodberg et al. 2002; Pedersen et al. 2003; Johnson & Marchant-Forde 2009). Shortly after farrowing, sows mostly lie in lateral recumbency with rapidly decreased responsiveness to their piglets (Jarvis et al. 1999; Pedersen et al. 2003). This decrease in activity in the early post-partum period is probably a way of protecting piglets from trapping events and crushing, as well as enabling them easy access to sow's udder and the warmth from her body (Pedersen et al. 2003). As stated by Pedersen et al. (2003), the ensuing increase in sow's responsiveness is connected to the increase in activity approximately 10 hours post-partum and it seems to be connected to more organised nursing patterns. Even so, post-partum period is characterised by sow's inactivity which lasts approximately 72 hours (Nicolaisen et al. 2019).

According to a study by Jensen (1986), sows' frequency of foraging and locomotion activity increased between the first and the fourth week post-partum. This corresponds with the fact, that sows spend first two to three days in their nest with piglets, then begin to forage closer to their herd and approximately ten days post-partum eventually abandon the nest and lead the piglets to the sounder (Johnson & Marchant-Forde 2009).

3.1.5 Sow responsiveness toward piglet vocalisation

A piglet trapping event is a life-threatening situation for the trapped piglet and is accompanied by loud vocalisation. According to Weary and Fraser (1995), piglet screams are a form of honest signalling known in the communication in the animal kingdom. Illmann et al. (2013) analysed distress vocalisation in piglets during a trapping simulation experiment. They (Illmann et al. 2013) observed increased vocalisation in younger and lighter piglets compared to older and heavier piglets and confirmed the application of honest signalling of need to trapping events. As stated in Weary et al. (1996a), vocalisation of a piglet in need is of a higher rate and frequency compared to comfortable piglets and as a result, sows show stronger response to the piglets in need. Duration of a trapping event has an impact on the survival of a trapped piglet, thus according to results of Weary et al. (1996b) piglets generally survive a trapping event if the sow responds within 1 minute.

Loud piglet vocalisation also often occurs during piglet competition at the udder (Algers & Jensen 1985; Illmann et al. 2008). As suggested in Appleby et al. (1999), piglets use these loud calls to signal their mother sow they are being excluded from the current nursing episode. There are similarities between sow responsiveness to piglets' screams during fighting at the udder and during piglet trapping events, however, sows' reaction to fighting vocalisation is lower than the one that occurs during a trapping event (Illmann et al. 2008).

3.2 Farrowing crates and their effect on welfare

The conventional crating system of sows and their piglets has been developed in 1960s to maximise profit, minimise labour required to maintain hygiene and eliminate piglet mortality (Goumon et al. 2022) by controlling sows' postural changes after farrowing (Baxter et al. 2018). The floors of this housing system are partially or fully slatted and sows with their litters utilise crate space of approximately 1.23 m^2 that is situated within 3.6 – 4.6 m^2 crate (Baxter et al. 2018). It has been stated that approximately 95% of sows in the European Union, 83% in the USA, 70% in the United Kingdom are crated during farrowing as well as during the whole period of lactation (Johnson & Marchant-Forde 2009). This conventional type of housing not only restricts sow's ability to move, but it also prevents sows from the manifestation of their natural repertoire of behaviour, and as a result, this restrictive housing system gave rise to many welfare concerns (Baxter et al. 2011).

The inability to perform natural repertoire of behaviour such as the nest-building due to the lack of space or substrate leads to restlessness and frustration and is manifested through redirected nest-building behaviour such as pawing at the floor and bars of the crate and spending increased amount of time in oral activities such as bar-biting (Lawrence et al. 1994; Jarvis et al. 2001; Jarvis et al. 2002; Damm et al. 2003; Andersen et al. 2014; Yun et al. 2015) since the rails are the only material available for oral manipulation (Hartsock & Barczewski 1997). Moreover, as observed by Oliviero et al. (2008) and Gu et al. (2011) no opportunity to express nest-building behaviour prolongs farrowing and altogether increases heart rate (Damm et al. 2003) and stress level in permanently crated sows (Lawrence et al. 1994; Jarvis et al. 2001; Jarvis et al. 2002; Morgan et al. 2021; Plush et al. 2021).

Even though the farrowing crates were created to control postural changes and activity of sows, as stated in Andersen et al. (2014), permanently crated sows performed more quick flops when lying down after farrowing which is a high-risk situation for piglets. Furthermore, sows in conventional farrowing crates have limited contact with their litters, resulting in less sow-piglet interactions than in housing systems that enable free movement of sows (Chidgey et al. 2016; Singh et al. 2017).

Moreover, there is a higher risk of teat and limb lesions development in permanently crated sows compared to temporary or loose housed sows (Verhovsek et al. 2007; Ceballos et al. 2021). Equally important is the need of antibiotic or NSAIDs application, which according to Morgan et al. (2021) was higher in permanently crated sows and their piglets compared to sows and piglets housed in temporary crating. Thus, permanent crating impacts the physical health of sows as well as their piglets.

As a result of thorough scientific work and documentation of welfare issues connected with the permanent conventional farrowing crates, countries like Norway, Sweden and Switzerland have already banned the use of farrowing crates while New Zealand, Austria and Germany have announced their gradual withdrawal by 2025, 2033 and 2036, respectively (Goumon et al. 2022).

3.3 Temporary crating

The temporary crating of sows was developed as an alternative type of housing system that allows sows to move freely in a pen after crate opening that takes place few days after parturition (Chidgey et al. 2016; King et al. 2019; Goumon et al. 2022). Sows in temporary crating are confined only for a short period of time (usually few days before farrowing until the first 3 days post-partum) to control their postural changes and as a result minimise piglet mortality by crushing during this critical period.

Similar to sows in natural and semi-natural conditions, sows housed either in permanent or loose housing system remain mostly inactive during the first days post-partum (Hales et al. 2016). It is therefore most probable, that housing sows in crates during a short period of time post-partum and then enabling them free movement in a pen, would have less negative impact on their welfare compared to the farrowing crates.

3.3.1 Activity level

When studying the effect of crate opening on general activity level of temporarily crated sows, some authors observed increased activity after crate opening (day 3 – day 10) in temporarily crated sows compared to control group housed permanently (Berensmann et al. 2018; Goumon et al. 2018; King et al. 2019; Ceballos et al. 2020). However, others (Lambertz et al. 2015; Chidgey et al. 2016) found no difference in sows' activity level between temporary and permanent housing systems after crate opening (day 4 – day 7/ day 14). In addition, Höbel et al. (2018) observed more careful lying down behaviour in temporarily crated sows than in permanently crated sows.

Comparing temporarily crated sows with permanently crated control group, increase in motivated or explorative behaviour after crate opening was also observed (Chidgey et al. 2016; Ceballos et al. 2020; Loftus et al. 2020). The increased exploration could be a result of the novelty effect which was discussed in the study by King et al. (2019), where change in sows' behaviour was observed after crate opening, however, the performed behaviour during the following day was analogous to the one seen during pre-opening period. As a result, they suggested, that behavioural changes seen after crate opening might be due to the novelty of no confinement.

Once temporarily crated sows and piglets had the opportunity to use the whole pen area after crate opening, more sow-piglet interactions were observed than in permanently crated group (Chidgey et al. 2016; Singh et al. 2017; Ceballos et al. 2020; Loftus et al. 2020). On the contrary, King et al. (2019) found no difference in the number of sow's sniffing of the piglets when comparing periods before and after crate opening in temporary housing system.

3.3.2 Effect of housing system on sow responsiveness to piglet calls

As stated before, a piglet trapping event is often accompanied by piglet vocalisation. The vocalisation of younger and lighter piglets tends to be stronger in comparison to vocalisation observed in older and heavier piglets (Illmann et al. 2013). Even though sows are mostly inactive during the first 24 hours post-partum, they are still highly responsive to the piglet

vocalisation (Illmann et al. 2008). When they are housed in farrowing crates (Illmann et al. 2008) or in a loose housing system (Chaloupková et al. 2008), sows respond to piglet vocalisation during a trapping event or piglet competition for teats by performing a postural change. Melišová et al. (2014) found no difference in sows' reaction to real piglet crush calls between sows housed in pens and crates during the first three days post-partum. However, they (Melišová et al. 2014) as well as Singh et al. (2017) observed a higher probability of sow's response toward playback sound of a screaming piglet when housed in a pen than in a crate. On the contrary, relatively lower responsiveness to playback screams was seen in loosely housed sows (Chaloupková et al. 2008). Many authors hypothesised, that different response toward playback may be caused by different acoustical structure of the recorded piglet vocalisation. This was also supported by Chapel et al. (2018) who found out that trapped piglets have deeper calls than restraint ones, therefore, to bring unbiased results, maternal responsiveness toward piglet crush vocalisation should be tested only with recordings of trapped piglets.

3.3.3 Sow lie-down strategy

Compared to the very limited options of permanently crated sows, temporarily crated sows are given the opportunity to utilise the whole pen area after crate opening. When studying high-risk sow behaviour in group farrowing system, Marchant et al. (2001) labelled sow's lying down behaviour in the middle of the pen with the use of no support and situation, when sow was lying down in the pen while being surrounded by her piglets as two of four dangerous events that could result in a piglet crushing event. However, Höbel et al. (2018), observed more careful lying down behaviour performed by sows in farrowing pens than those in farrowing crates. Moreover, support features that could be used by the sow while lying down could also increase the safety of piglets that are spread out around the descending sow.

In order to motivate sows to use support while lying down, different support designs were tested e.g., plain/curved/multiple bar slope walls; rails or plain walls (Damm et al. 2006) to find the one, which would be preferred by sows. Results (Damm et al. 2006) showed no difference in sows' preference for a certain slope wall type, however, it showed sows' higher preference for either a plain wall or a plain slope wall rather than the use of farrowing rails while lying down. Moreover, sows showed preference for a certain spot in the pen, specifically, back wall of the pen regardless of the wall design. The importance of a support device in the pen was confirmed by Illmann et al. (2021) who observed the use of some support in 85% of the time during lying down after crate opening in temporarily crated sows. Furthermore, after crate opening, they (Illmann et al. 2021) saw an increased probability of sow lying down with a snout contact with piglets in the nest area, when higher percentage of piglets occupied it.

Taking all these results into an account, we can see that there are several factors affecting sow lie-down strategy and more research is needed to increase the safety of piglets while maintaining optimal welfare of sows and their piglets.

3.3.4 Piglet weight gain

Appropriate weight gain is a result of regular nutritive nursings. Comparing sow nursing behaviour in temporarily and permanently housed sows, Illmann et al. (2019) found no difference in the number of nutritive and non-nutritive nursings the day after crate opening and day 25, furthermore, no difference was observed in the nursing duration between temporarily and permanently crated sows shortly after crate opening (Pedersen et al. 2011; Chidgey et al. 2016; Singh et al. 2017). Interestingly, longer nursing episodes (Ceballos et al. 2020) with longer milk ejections were observed in temporarily crated sows (Pedersen et al. 2011) and altogether these sows spent more time performing nursing behaviour compared to permanently housed sows (Loftus et al. 2020).

Piglets housed with their mothers in temporary crating missed more milk ejections on day 11 and day 18 after crate opening (Singh et al. 2017) but no difference in the number of missed milk let-downs was observed on day 4 which was the day after crate opening (Singh et al. 2017; Illmann et al. 2019). Moreover, piglets tended to massage sow's teats more actively after crate opening (Chidgey et al. 2017).

When comparing piglet growth of offspring from differently housed sows, lowest weight gain at weaning was seen in piglets from gilts born and reared in pens that farrowed in a pen than under other conditions used in the experiment (gilts born, reared in a crate, farrowed in a crate / gilts born and reared in a crate, farrowed in a pen) (Chidgey et al. 2016). However, while majority of papers (Salaün et al. 2004; Caille et al. 2010; Lambertz et al. 2015; Condous et al. 2016; Mack et al. 2017; Singh et al. 2017; Goumon et al. 2018; Höbel et al. 2018; Spindler et al. 2018; Lohmeier et al. 2019; Choi et al. 2020; Loftus et al. 2020) found no difference in piglet body weight at weaning when comparing temporary and permanent housing system, there are observations of higher piglet weaning weight of piglets reared in temporary crating than of those reared in permanent crating (Farmer et al. 2006; Oostindjer et al. 2010; Pedersen et al. 2011; Chidgey et al. 2015; Nowland et al. 2019; Kinane et al. 2021; Morgan et al. 2021).

3.3.5 Piglet mortality

There are numerous causes of piglet mortality e.g., low viability, starvation, hypothermia, or diarrhoea, however, crushing is the most frequent cause of piglet deaths. Since the majority of liveborn piglet mortality occurs during the first 2 – 3 days post-partum with a subsequent decrease during the first week post-partum (Marchant et al. 2000; Kilbride et al. 2012), permanent crating until weaning seems unreasonable from the perspective of minimising piglet mortality as well as from the perspective of sow's welfare.

When comparing results of piglet mortality between temporary and permanently crated sows, different methodology of experiments must be taken into consideration. For instance, some authors (Caille et al. 2010; Chidgey et al. 2015) saw increased preweaning mortality in temporarily crated sows while Ceballos et al. (2021) found slightly higher mortality when the crate was opened on day 4 than on day 7 post-partum, but found no difference in total mortality when compared to permanently crated sows. Salaün et al. (2004) observed

increased mortality at the time of weaning after crate opening in temporarily crated sows compared to control group crated permanently, however, only when the sows were housed on slatted floor and did not see any difference in piglet mortality at weaning when the sows and piglets were housed on a straw bedding. Similarly, the majority of papers that compared temporary and permanent housing systems of sows show no difference in piglet mortality at the time of weaning (Pedersen et al. 2011; Lambertz et al. 2015; Chidgey et al. 2016; Condous et al. 2016; Singh et al. 2017; Höbel et al. 2018; Spindler et al. 2018; Lohmeier et al. 2019; Loftus et al. 2020; Choi et al. 2020; Kinane et al. 2021).

Piglet mortality of temporarily crated sows was lower when given into comparisson with loosely housed sows (Hales et al. 2015; Olsson et al. 2018) however, an impact of sow parity number on lower mortality was emphasized, showing that only sows during parity 3 and 4 achieved previously stated results (Olsson et al. 2018).

Additionally, Morgan et al. (2021) found a positive correlation between the time of confinement and piglet mortality when comparing temporary and permanent housing system. They stated that the duration of the restraint period effected the number of weaned piglets, which was according to their results higher in temporarily crated sows than in permanently crated sows.

4 Methodology

This experiment was carried out from December 2021 to November 2022 at the research farm of the Institute of Animal Science in Prague, Czech Republic. During the stated period, the experiment was divided into four segments. Duration of each individual segment was approximately one month.

4.1 Animals

A total of 15 healthy Large White x Landrace sows marked with a number on their back as well as by an ear tag were used in this experiment. Sows were inseminated with Large White x Pietrain boar semen. The observed sows were either primiparous or multiparous, the average parity was 1.73 ± 1.49. Altogether 236 piglets (200 liveborn; 36 stillborn) were born during this experiment. At the beginning of the experiment the litter size among sows varied from 8 to 16 piglets (13.33 ± 2.58). During the first 3 days of their life, all piglets received an iron injection. To enable an easy identification of potentially dead piglets as well as for the weight control, all piglets were marked by a number on their back and by an ear tag on the fourth day post-partum during the weight check. None of the piglets in this experiment was either tail docked or teeth clipped.

Sows and piglets had ad libitum access to drinking water through two nipple drinkers. Sows were fed standard lactation diet twice a day and were given 3 kg of chopped hay once a day.

Fig. 1 Histogram of the parity.

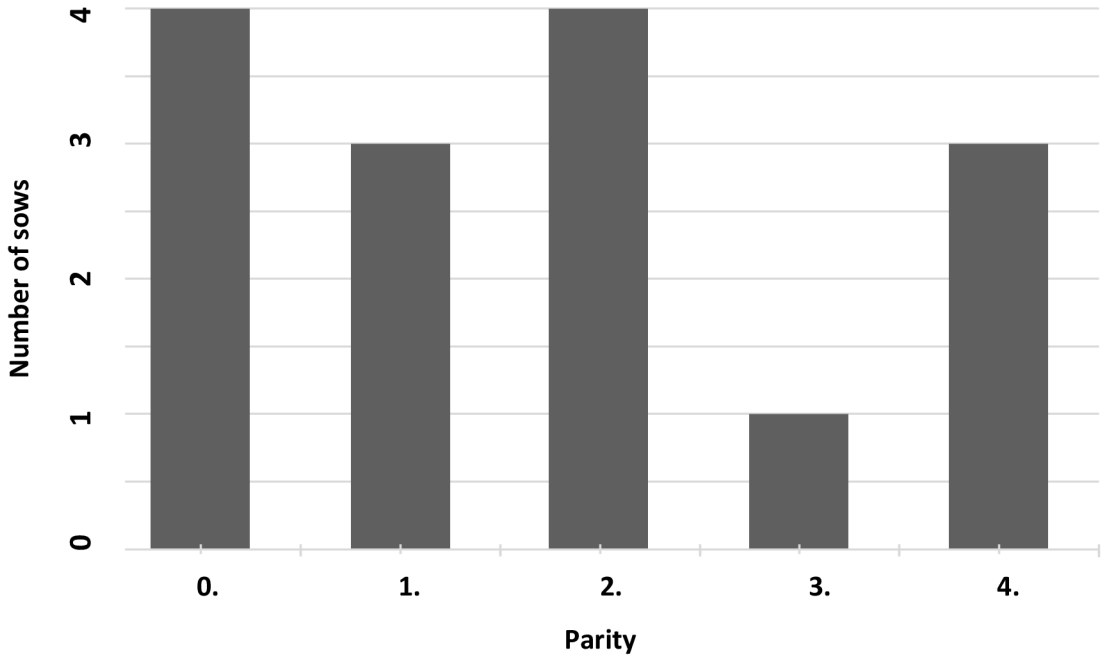
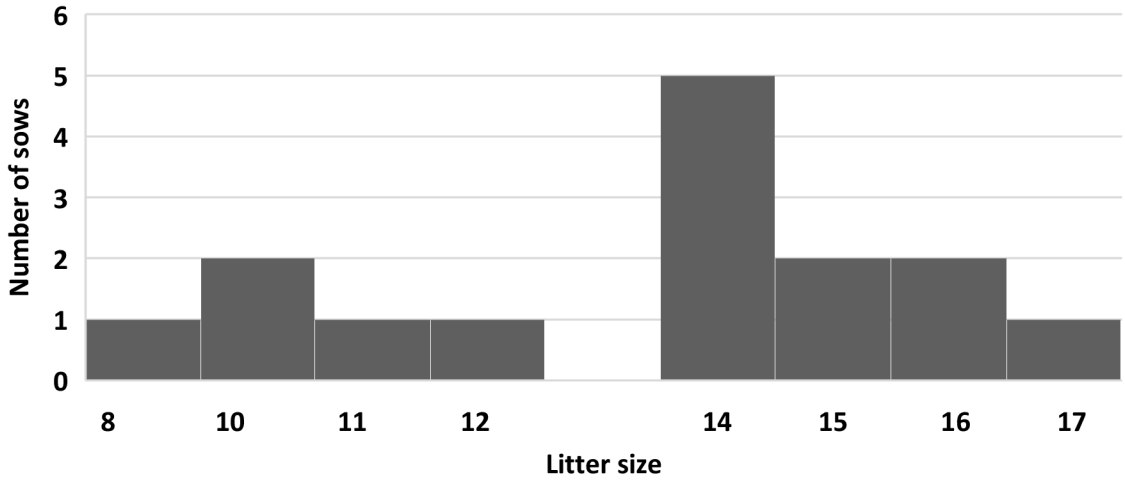


Fig. 2 Histogram of the litter size at the beginning of the experiment.

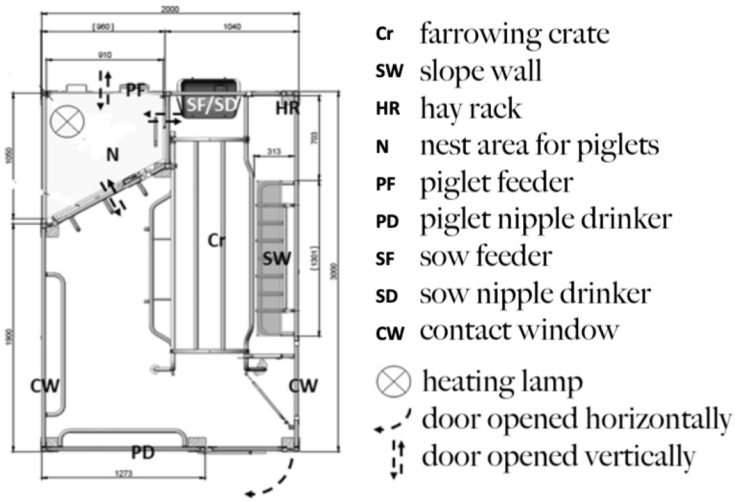


4.2 Housing

All sows and their piglets were housed in a room containing four WELLUP farrowing pens. Thanks to the movable bars, the farrowing pens could be easily changed into a farrowing crate and vice versa. While in the farrowing crate, the sow could utilise 2.2 m^2, the size of the farrowing pen after crate opening was 6 m^2. The nest area (part of the pen accessible only to the piglets) with the size of 0.8 m^2 accommodated up to 12 – 14 piglets until the age of four weeks. The roof of the nest area was equipped with a heating lamp.

To protect the piglets during sow's lying down behaviour, two walls were equipped with protection rails and one wall of the pen was equipped with a slope wall which could be used as a support by sows during lying down. The front part of the nest area was also protected by rails which had the function to protect the piglets from being crushed as well as enabled them to leave the nest area in situations when the sow blocked the entrance by her body.

All four WELLUP farrowing pens in this experiment had solid concrete flooring which was bedded with straw and were cleaned twice a day.



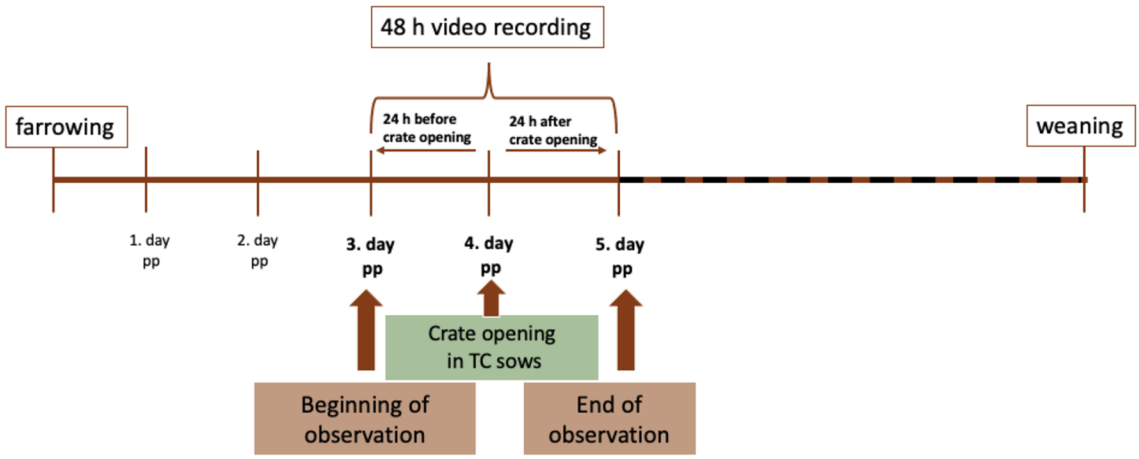
Picture 3 Design of the WELLUP farrowing pen with a legend (Goumon et al. 2018).

Pictures 4 & 5 The WELLUP farrowing pens in the experimental room (Sekyrová 2020).

4.3 Experimental design

Sows in this experiment were moved into the WELLUP farrowing pens at the end of their gestation. During farrowing, all sows were closed in the farrowing crates. According to the type of housing system used in the next stages of the experiment, two groups of sows were created: 8 TC sows (temporarily crated sows) and 7 PC sows (permanently crated sows). Recording of all sows started on day 3 post-partum and continued through day 4 and 5. The result was 48 h long video recording divided into two 24 h long periods (24 h before crate opening; 24 h after crate opening).

While PC sows stayed in the farrowing crate throughout the experiment, farrowing crate of TC sows was opened on day 4 and except for the nest area, sows were able to move freely in the WELLUP pen. The farrowing crates of TC sows were opened between 10 and 12 am.

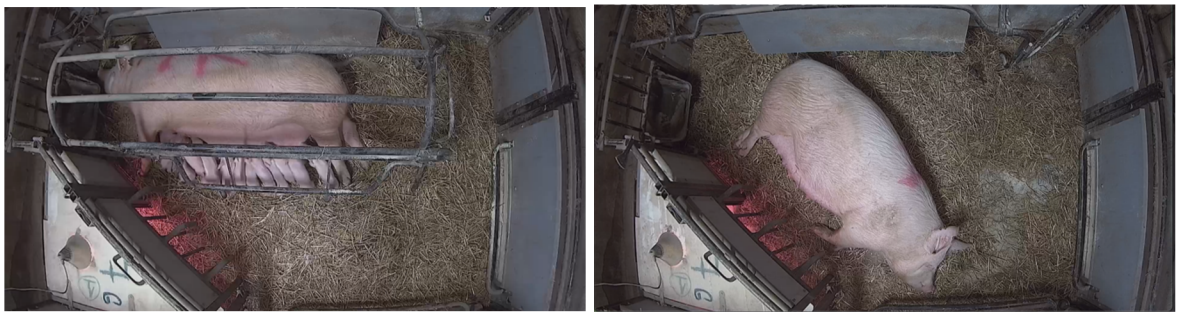


Picture 6 Timeline of the experiment.

4.4 Data collection

Behaviour of sows and their litters was continuously recorded during days 3, 4 and 5 post-partum. To create a 48 h video recording an overhead CCTV camera (Panasonic CCTV, WV CP 470, Osaka, Japan) with NUUO software (IP Surveillance System, NVR/DVR/NVDR, Taipei, Taiwan) was used in each pen. Recorded data were afterwards analysed using Microsoft Excel 2022 sheet. In temporarily crated sows, postural changes were analysed during 24 h period before crate opening and during the immediate 24 h period after crate opening. The analysed video recording of postural changes of permanently crated sows was 48 h long and was as well divided into two 24 h long periods.

A B



Pictures 7 & 8 Screenshots of the video recording: A) permanently crated sow; B) temporarily crated sow in the pen 24 h after crate opening.

4.5 Variables and definitions

All recorded data were analysed in an ethogram created in Microsoft Excel 2022. The ethogram was divided into 4 parts: general information, information about sow's postural changes, information about piglet trapping event and information about piglet location.

4.5.1 General information

Table 1 General information.

Variable	Definition
Type of the housing system	Temporary crating / permanent crating.
Date of the video recording	Date of the day during which sow's behaviour was recorded.
Farrowing day	Exact date of the farrowing.
Sow ID	Sow's identification number marked on her back as well as on her ear tag.
Parity	Number of sow's current parity.
Litter size at birth	Number of all piglets born (liveborn and stillborn).
Current litter size	Number of living piglets at the beginning of the experiment.

Pen number	Number of the WELLUP pen in which the sow was placed.
Phase	Temporary crated sows: -24 h before crate opening -24 h after crate opening. Permanently crated sows: -24 h before crate opening: first 24hour period of the video recording of a permanently crated sow -24 h after crate opening: second 24hour period of the video recording of a permanently crated sow.

4.5.2 Information about sow's postural changes

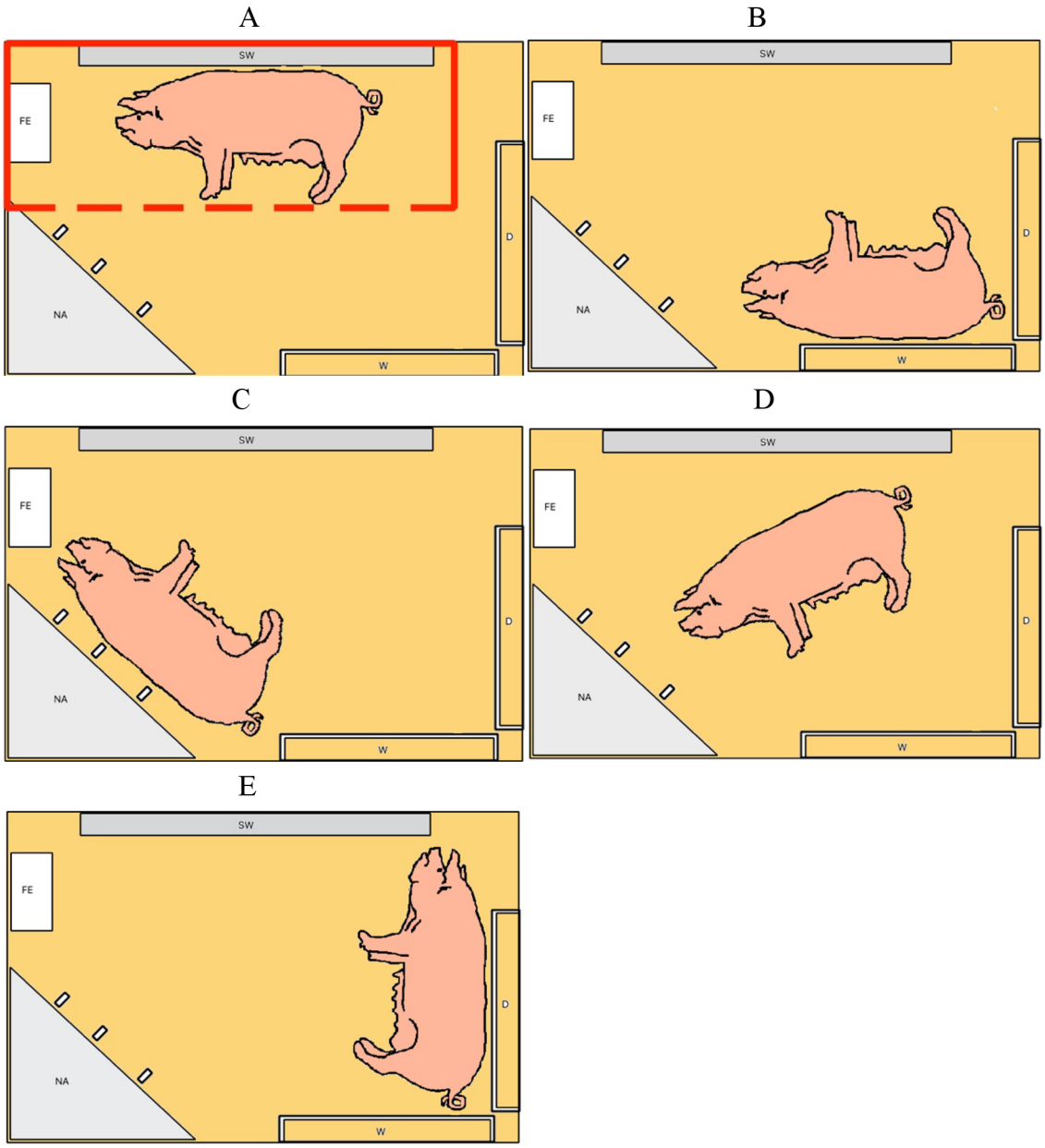
Sow's postural changes represent the main part of our data analysis. Lying down behaviour can be performed either from standing or sitting position, which was taken into consideration during analysis. Besides the lying down behaviour, rolling behaviour from one side to another or from belly to left/right side and vice versa was recorder in the ethogram as well as standing up behaviour. Standing up was influenced by many factors, therefore the reasons for standing up were also logged into the ethogram.

The design of the pen and pen features which could be utilised by sows as a support during lying down are of the major importance to prevent trapping events and piglet crushing. Therefore, use of support during lying down as well as the subsequent location of the sow in the pen was recorded during video analysis.

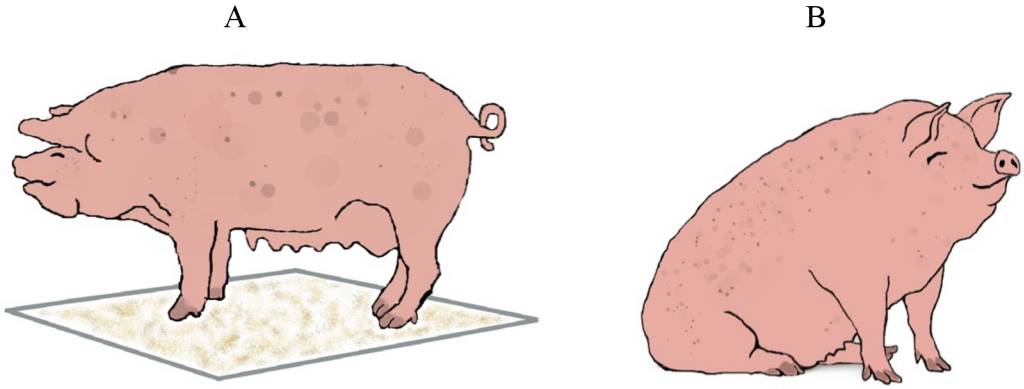
Table 2 Information about sow's postural changes.

Variable	Definition
Time of standing up behaviour	The exact time of standing up.
Reason for standing up	Reason why the sow stands up because of the factors in the area: Piglet noise in the pen – sibling competition, fighting, vocalisation, etc. Background noise out of the pen – noise from the surrounding area made by people, animals, or machines. Unknown – not defined / unknown.
Start of lying down behaviour	The exact time when the sow touched the ground with her forearm.
End of lying down behaviour	The exact time when sow's posterior part of body touched the ground.
Duration of lying down event	Time measured since the sow touched the ground with her forearm until she placed

	her posterior part of the body on the ground as well.
Type of event	Lying down - sow lies down from standing (standing-to-lying). Rolling - sow rolls body from left/right side to belly or vice versa. Sitting - sow is lying down from sitting position (sitting-to-lying).
Use of any support	Sow touches any support (wall, slope wall, door) during the lying down.
Touch of slope wall	Sow touches the slope wall during lying down.
Lying down in the middle of the pen	Sow lies down in the central part of the pen.
Sow location	SW – sow is lying close to the slope wall. M – sow is lying in the middle of the pen. W – sow is lying close to the wall on the opposite side of the slope wall. D – sow is lying close to the door - opposite of the feeder. NA – sow is lying in front of the nest area.
Side	R – lying on the right side. L – lying on the left side. M – lying on the belly; the udder is hidden.
Nose directed to the nest area	Sow's head is pointing to the nest area.
Sow's proximity to the nest area	Sow lies down in front of the nest area / in the middle of the pen with nose directed to the nest area / near wall with nose directed to the nest area.
Nursing after lying down	Sow performs nursing behaviour within first two minutes after lying down.



Pictures 9 - 13 Sow's locations in the pen: A) slope wall; B) wall; C) nest area; D) middle; E) door (Simanová 2023).



Pictures 14 & 15 Different starting positions before lying down: A) standing; B) sitting (Simanová V. 2023).

4.5.3 Information about piglet trapping event

Table 3 Information about piglet trapping events.

Variable	Definition
Trapping during lying down	A piglet is trapped under the sow while she is lying down.
Piglet's vocalisation after trapping	A piglet vocalises/screams when being trapped under the sow.
Localisation of trapping	Front - a piglet is trapped under the sow's anterior part of the body. Back - a piglet is trapped under the sow's posterior part of the body.
Sow's response	The way in which sow responds to a piglet trapping event. Stand - sow stands up or sits down. Turn - sow turns her head. No - no reaction.
Duration of sow's response (s)	Time after which the sow responds to a piglet trapping event. Measured from the beginning of a trapping event until the sow responds.
Number of trapped piglets	How many piglets were trapped under the sow during the performance of a postural change.
Specific number of the trapped piglet	Piglet's number marked on its back and on an ear tag.
Death of piglets	Death of piglet/s because of a trapping event.

4.5.4 Information about piglet location

Table 4 Information about piglet location in the pen during sow's postural change.

Variable	Definition
Number of piglets in the danger zone	Danger zone = area around the sow (except for the head) that equals the length of a piglet's body; piglets which are hidden behind the slope wall are not counted - not in danger.
Piglets in the pen	Number of piglets present in the open space of the pen.
Piglets in cluster	The whole litter in one cluster (in the proximity of one piglet's body length).

4.5.5 Statistical analysis

All data were analysed using SAS (SAS Institute Inc., Cary, NC, version 9.4). A linear mixed model (PROC MIXED) and generalised mixed model (PROC GLIMMIX) were used for the statistical analysis. The dependant variables were as follows: the number of postural changes, the number of piglet trapping events, the use of the slope wall, the use of some support, lying down in proximity to the nest area and the piglet weight at day 25 post-partum.

Least square means were computed for each level, their difference was tested using *t* test adjusted through Tukey-Kramer method.

Results were considered as statistically significant at $P \leq 0.05$.

5 Results

In this experiment, a total of one thousand two hundred and seventy-seven postural changes (standing up, standing-to-lying, sitting-to-lying, rolling) were observed and analysed 24 h after crate opening: 743 in temporary crating and 534 in permanent crating.

5.1 Postural changes

5.1.1 Postural changes after crate opening

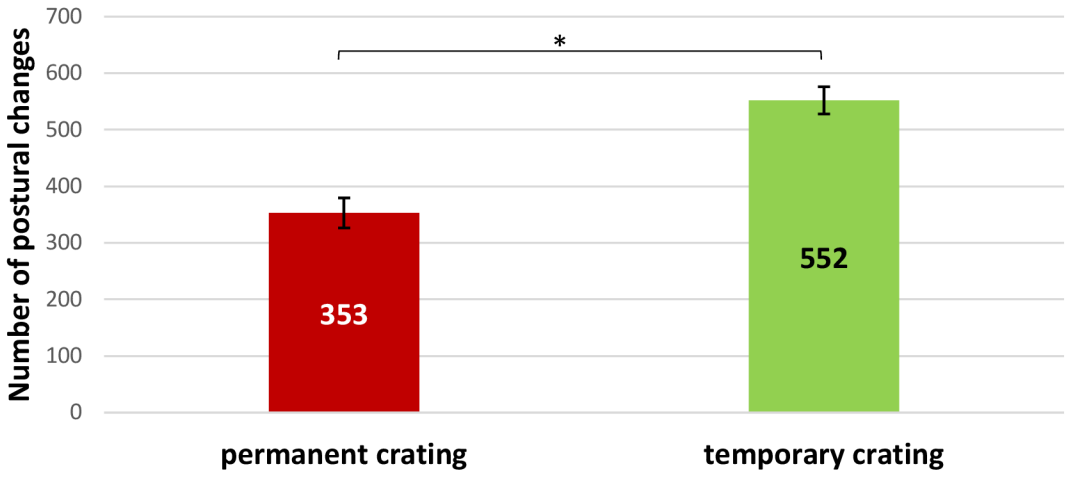
H1a: Sows in temporary crating perform more postural changes after crate opening than permanently crated sows.

In both housing systems 24 h after crate opening, we analysed the sum of 905 postural changes that might cause piglet trapping events and consist of standing-to-lying, sitting-to-lying, and rolling behaviour.

The housing system had a significant effect on the number of sows' postural changes 24 h after crate opening ($F_{1,15}$ = 5.60; P= 0.0318), with temporarily crated sows performing significantly more postural changes (Tukey-Kramer test, t= -2.37; P= 0.0318) compared to permanently crated sows (Fig. 3). Temporarily crated sows performed altogether 1. 56 times more postural changes 24 h after crate opening than permanently crated sows.

The parity significantly affected the number of postural changes ($F_{1,15}$= 16.95; P= 0.0009). Sows with higher parity had less postural changes. The effect of the litter size was not significant ($F_{1,15}$= 0.43; NS).

Fig. 3 A comparison between the number of postural changes in permanently and temporarily crated sows 24 h after crate opening. Least-square means ± SE, *P< 0.05.



The housing system significantly affected the number of rolling ($F_{1,15}$ = 21.59; P= 0.0003) as well as the number of standing-to-lying ($F_{1,15}$ = 6.09; P= 0.0261) with temporarily crated sows performing more rolling (Tukey-Kramer test, t= -4.65; P= 0.0003) and standing-to-lying (Tukey-Kramer test, t= -2.47; P= 0.0261) than permanently crated sows. Sitting-to-lying was not affected by the housing system ($F_{1,6.92}$ = 1.27; P= NS) (Fig. 4).

The parity had a significant effect on the number of rolling ($F_{1,15} = 21.62$; P= 0.0003) and the number of standing-to-lying ($F_{1,15} = 6.39$; P= 0.0232). Sows with higher parity performed rolling and standing-to-lying less often. Sitting-to-lying was not significantly affected by the parity ($F_{1,14} = 3.99$; P= NS).

The litter size significantly affected the number of standing-to-lying ($F_{1,15} = 7.16$; P= 0.0173). Sows with bigger litters lied down more often. The rolling ($F_{1,15} = 0.66$; P= NS) and sitting-to-lying ($F_{1,8.31} = 0.25$; P= 0.6299) was not significantly affected by the litter size.

Fig. 4 A comparison between the number of specific postural changes between permanently and temporarily crated sows 24 h after crate opening. Least-square means ± SE, *P< 0.05; *** P< 0.001; NS – not significant.

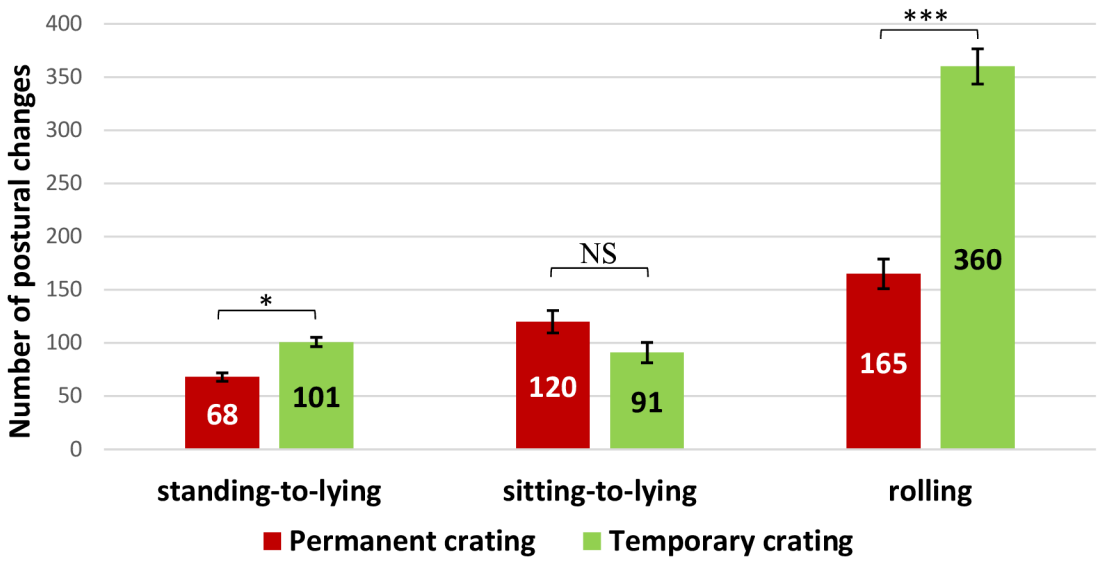


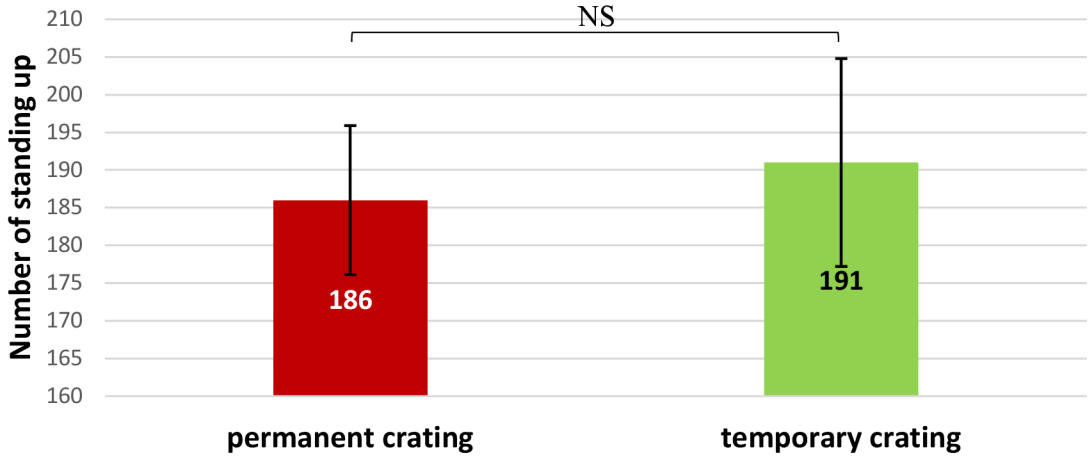
Table 5 Percentual increase or decrease in the number of postural changes 24 h after crate opening in temporarily crated sows compared to permanently crated sows.

Housing system	**Permanent crating**	**Temporary crating**	
Phase	**24 h after crate opening**	**24 h after crate opening**	**Increase / decrease of postural changes (%)**
Type of event	**Postural changes (n)**	**Postural changes (n)**	
Standing-to-lying	68	101	↑ 48.53%
Sitting-to-lying	120	91	↓ 24.17%
Rolling	165	360	↑ 118.18%
Sum of postural changes	353	552	↑ 56.37%

5.1.2 Reasons for standing up

A total of 377 standing up behaviours were seen in both permanently and temporarily crated sows 24 h after crate opening.

Fig. 5 A comparison between the number of standing up in permanently and temporarily crated sows 24 h after crate opening. NS – not significant.



The number of standing up because of the background noise out of the pen was significantly affected by the parity ($F_{1,15}$ = 5.57; P= 0.0323). Sows with higher parity stood up because of the background noise out of the pen less often. The housing system ($F_{1,15}$ = 0.19; P= NS) (Fig. 6) and the litter size ($F_{1,15}$ = 0.25; P= NS) had no significant effect on the number of standing of because of the noise out of the pen.

No significant effect of the housing system ($F_{1,15}$ = 3.70; P= NS) (Fig. 6), the litter size ($F_{1,15}$ = 1.60; P= NS) or the parity ($F_{1,15}$ = 0.57; P= NS) was found on the number of standing up because of the piglet noise.

Fig. 6 A comparison between the number of standing up caused by different reasons in permanently and temporarily crated sows 24 h after crate opening. NS – not significant.

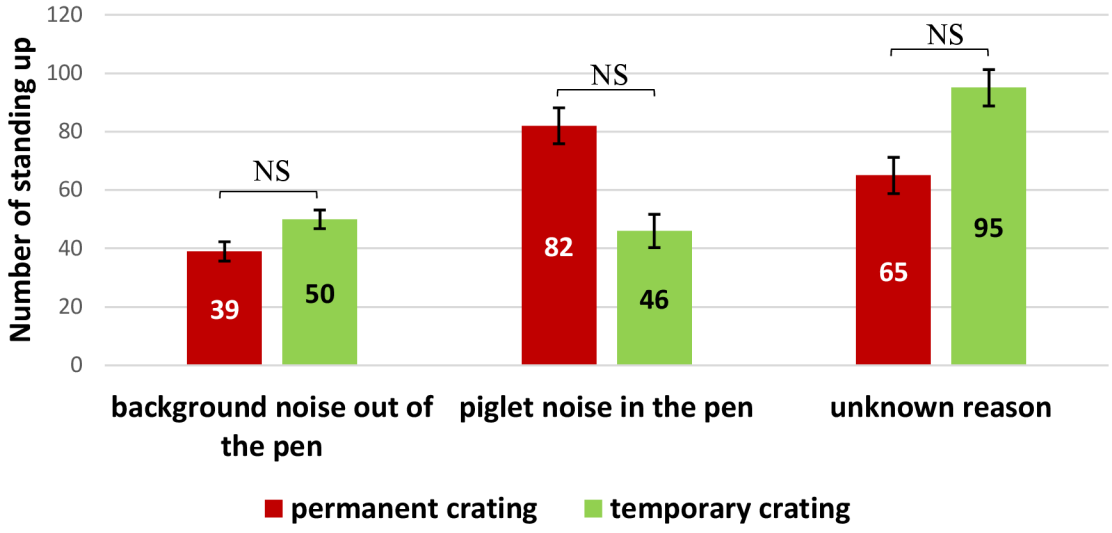


Table 6 Percentual increase or decrease in the number of standing up behaviour 24 h after crate opening in temporarily crated sows compared to permanently crated sows.

Housing system	**Permanent crating**	**Temporary crating**	
Phase	**24 h after crate opening**	**24 h after crate opening**	**Increase / decrease (%)**
Type of event	**Standing up (n)**	**Standing up (n)**	
Background noise out of the pen	39	50	↑ 28.21%
Piglet noise in the pen	82	46	↓ 43.90%
Unknown reason	65	95	↑ 46.15%
Sum of standing up	186	191	↑ 2.69%

5.2 Piglet trapping events

H1b: Higher number of postural changes in temporary crating after crate opening might cause more piglet trapping events.

Out of 905 high-risk postural changes (standing-to-lying, sitting-to-lying, rolling) both in permanently and temporarily crated sows, a total of 5 trapping events of 6 trapped piglets were observed 24 h after crate opening (Table 7).

Table 7 Summary of trapping events.

Housing system	**Phase**	**Number of trapping events**	**Number of trapped piglets**	**Fatal trapping**
Permanent crating	24 h after crate opening	1	1	0
Temporary crating	24 h after crate opening	4	5	0

The number of postural changes had no significant effect on the number of trapping events ($F_{1,4}$= 2.07; NS). The effect of the housing system ($F_{1,4}$= 0.42; NS), parity ($F_{1,4}$= 0.45; NS) and the litter size ($F_{1,4}$= 0.31; NS) was also not significant.

H2: Sow's reaction to piglet vocalisation will be faster in temporary crating after crate opening thanks to better mobility in the pen area.

In our experiment, out of 905 high-risk postural changes (standing-to-lying, sitting-to-lying, rolling) both in permanently and temporarily crated sows 24 h after crate opening, only 1 trapping event accompanied by piglet vocalisation with a subsequent sow response was observed in temporarily crated sows and no such event was seen in permanently crated sows (Table 8).

Table 8 Summary of trapping events accompanied by piglet vocalisation with subsequent sow response.

Housing system	Number of trapped piglets	Piglet vocalisation	Sow response	Sow reaction time (s)	Fatal trapping
PC	1	-	-	-	No
TC	1	✓	✓	4	No
TC	1	✓	-	-	No
TC	2	✓	-	-	No
TC	1	✓	-	-	No

5.3 Sow lie-down strategy

5.3.1 The use of the slope wall during lying down

H3a: Temporarily crated sows use the slope wall less often during lying down 24 hours after crate opening than permanently crated sows.

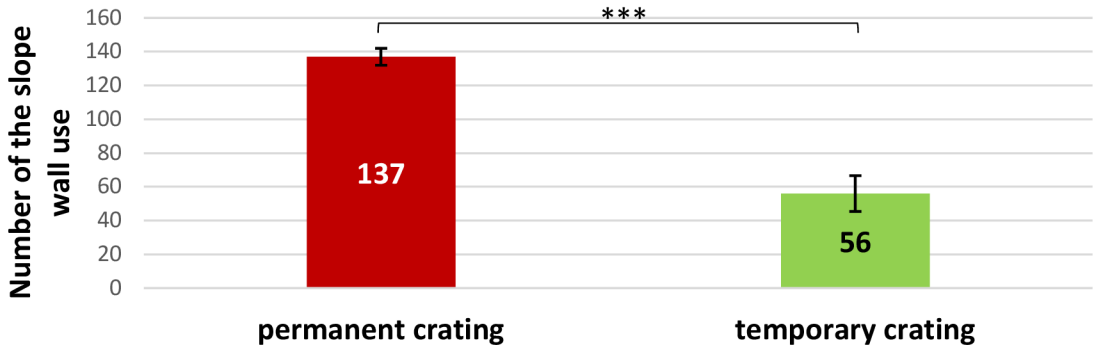
In both housing systems 24 h after crate opening, out of 380 lying down events (standing-to-lying, sitting-to-lying) sows used the slope wall in 193 cases (50.80%).

The use of the slope wall was significantly affected by the housing system ($F_{1,15}$= 36.45; P<0.001), with permanently crated sows using the slope wall significantly more often than temporarily crated sows (Tukey-Kramer test, t= 6.04; P<0.001) (Fig. 7).

The litter size significantly affected the use of slope wall ($F_{1,15}$= 12.85; P=0.0027). Sows with more piglets in their litter used the slope wall more often.

The effect of the parity was not significant ($F_{1,15}$= 3.46; NS).

Fig. 7 A comparison between the use of slope wall by sows in permanent and temporary crating. Least-square means ± SE, ***P< 0.001.

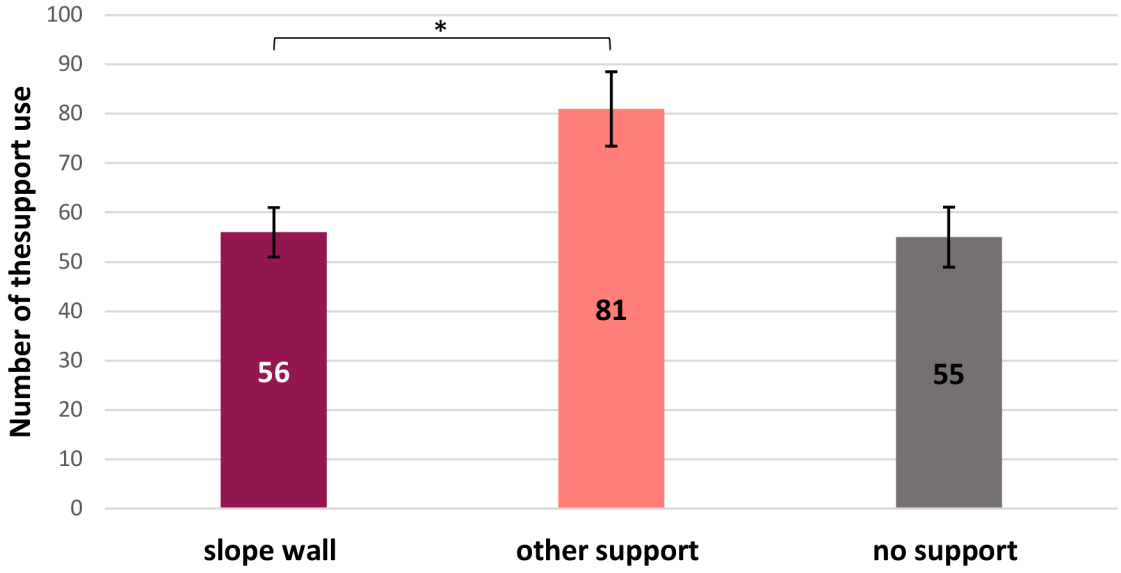


5.3.2 The use of other support during lying down

H3b: The decrease in the use of slope wall in temporarily crated sows 24 hours after crate opening is compensated by the increased use of other pen support during lying down.

The use of other support while lying down in temporarily crated sows 24 h after crate opening significantly affected the use of the slope wall ($F_{1,8}$= 7.61; P=0.0247). With the increased use of other pen support (42.18%), the use of the slope wall decreased (29.16%) (Fig. 8).

Fig. 8 The use of support by temporarily crated sows 24 h after crate opening. Least-square means ± SE, *P< 0.05.



5.3.3 Proximity to the nest area

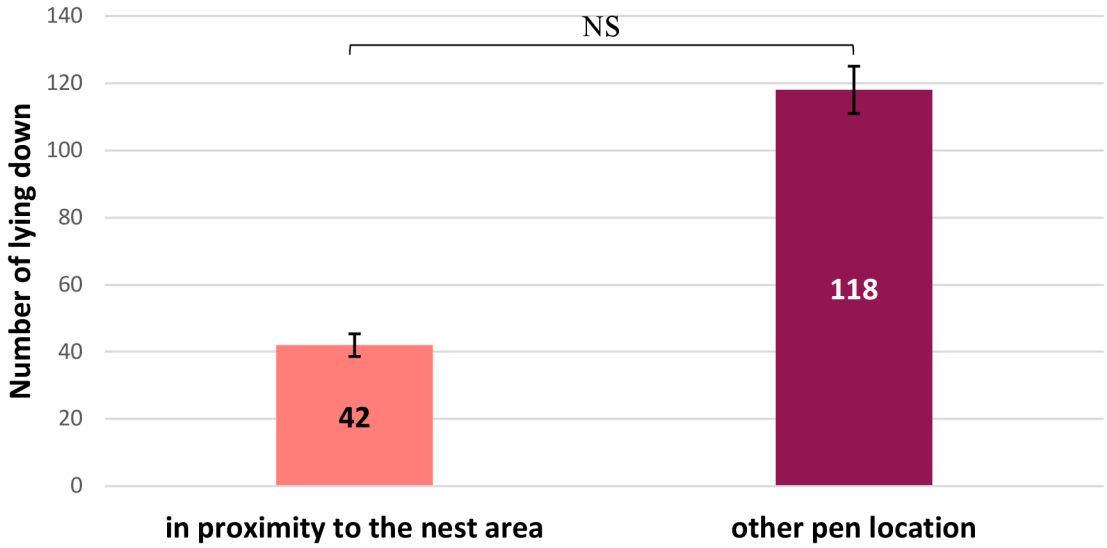
H4: Temporarily crated sows are after the crate opening more likely to lie down near the nest with a higher percentage of piglets in the nest.

The majority of the piglets (>50% of piglets in the litter) occupied the nest area during 160 lying down events. In these situations, sows used other locations farther away from the nest area more often than those that were in proximity to the nest area (Fig. 9).

Higher percentage of piglets occupying the nest area had no significant effect on sows' lying down closer to the nest area (26.25%) ($F_{1,183}$= 1.00; NS).

The parity had also no significant effect on sows' lying down in proximity to the nest area ($F_{1,183}$= 2.27; NS).

Fig. 9 Sows‘ lying down locations in the pen when majority of the piglets occupied the nest area. Least-square means ± SE, NS – not significant.



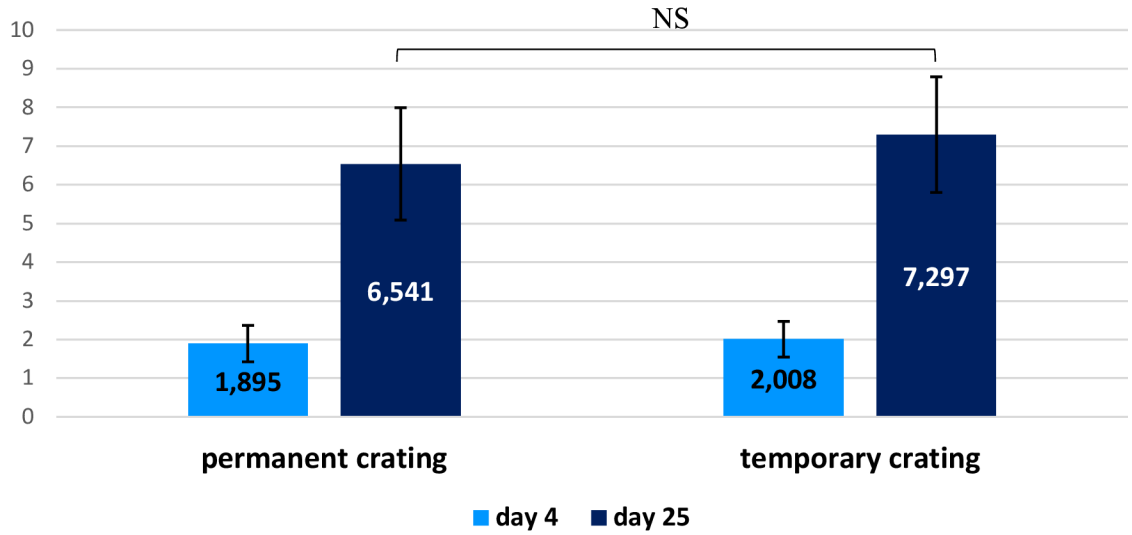
5.4 Piglet weight gain and fatal trapping events

5.4.1 Piglet weight gain

The results from piglet weight check on day 4 and day 25 did not differ between permanent and temporary crating (Fig. 10).

No significant effect of the housing system ($F_{1,6.95}$= 2.40; NS), the litter size ($F_{1,13.7}$= 3.28; NS) or the parity ($F_{1,17.1}$= 2.48; NS) was found on the piglet weight at day 25.

Fig. 10 The average piglet weight. NS – not significant.



5.4.2 Fatal trapping events

H5: The proportion of fatal trapping events in both housing systems will not significantly differ.

Out of 905 high-risk postural changes (standing-to-lying, sitting-to-lying, rolling) in both housing systems 24 h after crate opening, no fatal trapping events were observed.

During the time of video analysis, no other piglet mortality was observed.

5.5 Hypotheses assessment

Hypothesis	Assessment
H1a: Sows in temporary crating perform more postural changes after crate opening than permanently crated sows.	**Hypothesis confirmed.** There was a significant effect of the housing system on the number of postural changes. Temporarily crated sows performed altogether 1.56 times more postural changes 24 h after crate opening than permanently crated sows.
H1b: Higher number of postural changes in temporary crating after crate opening might cause more piglet trapping events.	**Hypothesis rejected.** The number of postural changes had no significant effect on the number of trapping events.
H2: Sow's reaction to piglet vocalisation will be faster in temporary crating after crate opening thanks to better mobility in the pen area.	**Not analysed.** A statistical analysis was not possible due to the low number of data collected during our observation.
H3a: Temporarily crated sows use the slope wall less often during lying down 24 hours after crate opening than permanently crated sows.	**Hypothesis confirmed.** The use of the slope wall was significantly affected by the housing system. Sows in temporary crating 24 h after crate opening used the slope wall 2.5 times less often than permanently crated sows.
H3b: The decrease in the use of slope wall in temporarily crated sows 24 hours after crate opening is compensated by the increased use of other pen support during lying down.	**Hypothesis confirmed.** With the increased use of other pen support, the use of the slope wall significantly decreased. 24 h after crate opening, temporarily crated sows used other support 1.44 times more often than the slope wall.
H4: Temporarily crated sows are after crate opening more likely to lie down near the nest with a higher percentage of piglets in the nest.	**Hypothesis rejected.** Higher percentage of piglets in the nest area had no significant effect on sow lying down in proximity to the nest area. When majority of the piglets occupied the nest area, sows used more often other pen locations farther away from the nest area (73.75%) than those in proximity to the nest area (26.25%).
H5: The proportion of fatal trapping events in both housing systems will not significantly differ.	**Not analysed.** No fatal trapping events were observed during our experiment.

6 Discussion

6.1 Sows' postural changes

6.1.1 Postural changes after crate opening

H1a: Sows in temporary crating perform more postural changes after crate opening than permanently crated sows.

This master's thesis demonstrates that the housing system, specifically temporary crating has a significant effect on the increased number of postural changes performed by sows after crate opening at day 4 post-partum. In our experiment, there was a 56.37% increase in the number of postural changes in temporarily crated sows 24 h after crate opening compared to permanently crated sows. The increase in activity after crate opening in temporarily crated sows compared to permanently crated sows was seen in previous studies (Berensmann et al. 2018; Goumon et al. 2018; King et al. 2019; Ceballos et al. 2020). However, it should be noted, that although in some studies (Goumon et al. 2018; King et al. 2019) similar postural changes like in our experiment were defined as activity, for example Ceballos et al. (2020) included behaviour such as eating, drinking, nursing, vacuum chewing etc. into their definition of activity, while for instance Berensman et al. (2018) using 3-axis accelerometer assessed activity only based on standing or non-standing position. It is therefore important to take these differences in methodology into consideration when comparing the exact results.

Importantly, Goumon et al. (2018) found only a short-term effect of crate opening on the increased sow activity and on day 25 post-partum, they observed similar activity levels in temporarily and permanently crated sows. Moreover, King et al. (2019) connected the increased activity after crate opening to the novelty effect because of its short occurrence during their observation, however, they observed only a short period in early lactation. Since in our experiment, only a short period during early lactation was observed as well, observation of the number of postural changes during the late lactation period in the future would help clarify, whether the crate opening has only a short-term effect on the increased number of postural changes and it could be related to the novelty effect and the need for exploration, or whether it has a long-term effect and sows would be more active during the whole period of lactation.

In our experiment, the most dominant increase (+118.18%) was seen in rolling behaviour, which corresponds with previous findings (Bradshaw & Broom 1999; Hales et al. 2016; Goumon et al. 2018). It has been suggested (Valros et al. 2003) that higher number of postural changes may be a coping mechanism used by sows to prevent piglets from stimulating the udder, since besides lying on the udder, it is the only way the sow can control udder stimulation when housed in a pen or a crate. Moreover, Hales et al. (2016) mentioned a possible explanation for the increase in the rolling behaviour in loose housed sows, and according to them, increased rolling might be related to the termination of nursing. However, when comparing temporary and permanent crating, Illmann et al. (2019) saw neither short-term nor long-term effect of the housing system on the proportion of nursings terminated by sows performed by rolling, sitting, or standing up. Therefore, more research is required to

come up with a conclusive explanation of the increase in the rolling behaviour seen in our results as well as in the results of previous studies.

6.1.2 Reasons for standing up

Our results show an insignificant increase in the overall standing up behaviour in temporarily crated sows in comparison to sows housed permanently. Looking at the specific reasons for standing up, our results suggest that the increase in the standing up because of the background noise out of the pen (+ 28.21%) and the unknown factors (+ 46.15%) in temporarily crated sows compared to permanently crated sows might be connected to the increased motivated or explorative behaviour. Sows with a higher parity number stood up less often because of the background noise out of the pen, which could be explained by a higher level of habituation to the noises in the environment of pig husbandry. Another possible explanation of the decrease in standing up in older multiparous sows could be connected to the fact, that these sows are often heavier than younger primiparas, thus they may have difficulties to stand up.

When sows stood up because of the unknown reasons, this was in many cases followed by the pen exploration. Although we did not focus on explorative behaviour in our experiment, we think that there are parallels between our results and results of Chidgey et al. (2016), Loftus et al. (2020) and Ceballos et al. (2020) who observed an increase in the explorative behaviour after crate opening and defined it mostly as pen directed behaviour such as sniffing, rooting or digging in the pen. Similar behaviour was seen also during our observation, however, as stated before, more specific results of the behaviour manifested subsequently after standing up would be needed to confidently connect our observation of standing up behaviour to the explorative or motivated behaviour. Moreover, as mentioned before, it would be beneficial to also observe the period during late lactation in the future, which would provide more information and which might help with the clarification of whether there is a connection between standing up, the explorative behaviour and the novelty effect.

Interestingly, in comparison to permanently crated sows, there was a decrease in the number of standing up behaviour caused by piglets (- 43.90%) observed in temporarily crated sows. The decrease in the number of standing up behaviour caused by piglets could be connected to the increased number of rolling mentioned above. Since rolling requires less energy than standing up and helps to prevent the stimulation of sow's udder by piglets in the same way, there is a possibility, that when housed in a pen, sows prefer rolling behaviour over standing up behaviour in those situations. Moreover, we also suggest that crate opening could have a calming effect on sows in connection to patience during post-ejection massage and during piglet fights at the udder, maybe thanks to the possibility of using larger space and finding more comfortable lying positions and therefore performing less standing up behaviour.

6.2 Sow responsiveness to piglet vocalisation

H2: Sow's reaction to piglet vocalisation will be faster in temporary crating after crate opening thanks to better mobility in the pen area.

In our experiment, only one trapping event in a temporarily crated sow 24 h after crate opening accompanied by piglet vocalisation with a subsequent sow response was observed, thus, we were not able to compare the responsiveness between temporarily and permanently crated sows.

Interestingly, three trapping events that were accompanied by piglet vocalisation received no response from the sow. This observation differs from the observation of Chaloupková et al. (2008), in whose experiment sows responded to piglet vocalisation in 80% of the trapping events. While in their experiment, all sows were in their second parity, the parity of sows used in our experiment varied between 0 and 4. Sows with higher parity number tend to be heavier, and therefore we might hypothesise that higher body weight of multiparous sows in our experiment might have affected their mobility and with that their responsiveness toward piglet crush calls.

The effect of the housing system on sow responsiveness was previously studied by Melišová et al. (2014). Comparing permanent and temporary crating on day 3 post-partum, they (Melišová et al. 2014) saw no effect of the housing system on sows' reaction toward real crush calls but similarly to Singh et al. (2017) they saw greater reaction of temporarily crated sows to playback crush calls. However, in loosely housed sows, the responsiveness toward playback piglet vocalisation was lower compared to the real crush calls (Chaloupková et al. 2008). Moreover, decrease in the sow responsiveness from 12 h (50%) to 24 h (25%) post-partum was observed (Chaloupková et al. 2008).

This variability in results might have been caused by different acoustical structure of the crush calls audio recordings, since as seen in Illmann et al. (2013) the age as well as the weight of the piglets affects the intensity of the vocalisation and moreover, there is also a difference in the acoustical structure of the vocalisation between restrained and trapped piglets (Chapel et al. 2018). These factors as well as the time of the observation could have caused the inconsistency of the results in the mentioned papers, therefore we suggest, that to clarify this aspect of sows' maternal behaviour, the methodology in future experiments should be more uniform.

6.3 Sow lie-down strategy

6.3.1 Use of the slope wall and other support

H3a: Temporarily crated sows use the slope wall less often during lying down 24 hours after crate opening than permanently crated sows.

H3b: The decrease in the use of slope wall in temporarily crated sows 24 hours after crate opening is compensated by the increased use of other pen support during lying down.

Our experiment showed that the housing system had a significant effect on the use of the slope wall 24 h after crate opening. During this period, temporarily crated sows used the slope wall less often than permanently crated sows. However, the litter size significantly affected sows' behaviour and sows with bigger litters used the slope wall more often. This effect of the litter size on sows' behaviour might decrease the risk of trapping events in hyperprolific sows. Moreover, our results showed that the lower frequency of the slope wall use (29.16%) 24 h after crate opening in temporarily crated sows was compensated by an increase in the use of other pen support (42.18%) which might prevent many piglet trapping events. These results also show that temporarily crated sows in our experiment preferred the rails over the slope wall while lying down 24 h after crate opening which is contradictory to Damm et al. (2006) who saw higher preference of the slope wall or a plain wall over rails. However, this support preference could have been influenced by the fact, that they (Damm et al. 2006) observed sows in their last trimester of gestation and not during the early post-partum lactation period as in our experiment.

Altogether, temporarily crated sows 24 h after crate opening in our experiment used some support (slope wall or rails) while lying down in ≈ 70% of lying down events. These results are similar to the findings of Illmann et al. (2021), who observed 85% use of some support 24 h after crate opening in temporarily crated sows.

Undoubtedly, sows prefer some sort of support while lying down during the early lactation period. However, further research is required to create a pen design that would be frequently used and preferred by the sow during lying down and which, while keeping welfare in mind, would create a safe environment for piglets as well.

6.3.2 Proximity to the nest area

H4: Temporarily crated sows are after crate opening more likely to lie down near the nest with a higher percentage of piglets in the nest.

Enabling sows to move freely in the pen after crate opening allows them to choose the most ideal lying down spot. Moreover, they are allowed to interact more with their piglets, which may lead to improvement in mother-piglet bond, their welfare and piglet development (Jensen 1988). We predicted that after crate opening, sows will more likely utilise the pen area closer to the nest area and lie down with their nose directed to the nest area once it is occupied by the majority of the piglets in the litter. This need for closeness to piglets was seen in Illmann et al. (2021), however, during our experiment, sows tended to lie down farther away from the nest area, even though it was occupied by a greater number of piglets. We could hypothesise that this behaviour could have been affected by the behaviour of piglets in the pen area, who, for example, by performing play or fight behaviour blocked sow's access to lying down spots near the nest area, or another explanation could be that even a small number of piglets present in the pen area satisfied sow's need for closeness with her litter as well as mother-piglet interactions. Knowing whether sows prefer lying down in proximity to their litter would be beneficial for the pen design adjustments, therefore, more research is required.

6.4 Piglet weight gain and trapping events

6.4.1 Piglet weight gain

Low piglet body weight at weaning and altogether low piglet weight gain are one of the main reasons why farmers are hesitant to use temporary crating over conventional farrowing crates. In our experiment, the housing system had no significant effect on the average piglet weight at day 25 post-partum.

Similar to the results of our experiment, there are studies (Salaün et al. 2004; Caille et al. 2010; Lambertz et al. 2015; Condous et al. 2016; Mack et al. 2017; Singh et al. 2017; Goumon et al. 2018; Höbel et al. 2018; Spindler et al. 2018; Lohmeier et al. 2019; Choi et al. 2020; Loftus et al. 2020) showing that temporary crating has no negative impact on piglet body weight at weaning compared to permanent crating. Moreover, other papers show that temporary crating can even improve piglet growth performance (Farmer et al. 2006; Oostindjer et al. 2010; Pedersen et al. 2011; Chidgey et al. 2015; Nowland et al. 2019; Kinane et al. 2021; Morgan et al. 2021) and result in higher body weight at weaning compared to piglets housed and reared with their mothers in permanent crating. Still, further research in this area is required to create strong and bulletproof arguments that would help persuade farmers into implementation of temporary crating in pig husbandry.

6.4.2 Trapping events

H1b: Higher number of postural changes in temporary crating after crate opening might cause more piglet trapping events.
H5: The proportion of fatal trapping events in both housing systems will not significantly differ.

Farmers are mostly afraid of the increase in the number of the piglet trapping events after crate opening in temporarily crated sows which might be potentially fatal for the piglets. However, although we observed an increased number of postural changes 24 h after crate opening in temporarily crated sows (+ 56.37%), its effect on the number of trapping events was not significant (4 trapping events). Moreover, no significant effect of the housing system on the number of trapping events was found. These results are contradictory to the results seen in Melišová et al. (2014) who observed an increase in the number of postural changes in temporarily crated sows, and as a result an increase in the number of trapping events compared to permanently crated sows. However, they (Melišová et al. 2014) observed a 72 h long period since the birth of the first piglet, whereas in our experiment, the third day post-partum was the day of the beginning of our observation. Different results seen in our experiment compared to Melišová et al. (2014) suggest that if the sows are housed in a pen from day 4 post-partum onward, the increase in the number of postural changes does not pose a threat to the safety of piglets, and as a result it indicates that temporary crating might be a safe alternative housing system.

No fatal trapping events were observed during our experiment in permanently, as well as temporarily crated sows 24 h after crate opening. Many papers (Pedersen et al. 2011; Lambertz et al. 2015; Chidgey et al. 2016; Condous et al. 2016; Singh et al. 2017; Höbel et

al. 2018; Spindler et al. 2018; Lohmeier et al. 2019; Loftus et al. 2020; Choi et al. 2020; Kinane et al. 2021) showed no difference in piglet mortality between temporary and permanent crating system at the time of weaning. Since in our experiment, we focused only on a short period during early lactation and did not analyse overall piglet mortality at the time of the weaning, we believe that further research would be required for us to confidently support previously mentioned papers. However, even though the observed period in this experiment was short, we believe that these results are crucial for the discussion with farmers about the implementation of temporary crating into pig husbandry.

7 Conclusion

This diploma thesis demonstrates that temporary crating has a significant effect on the increased number of postural changes such as standing-to-lying, sitting-to-lying and rolling performed by sows after crate opening at day 4 post-partum. The observed increase in the number of postural changes, however, does not affect the number of piglet trapping events. Nevertheless, it is still questionable, whether crate opening has only a short-term effect on sows' behaviour and should be therefore considered as the novelty effect or whether this increase in the number of postural changes 24 h after crate opening would be long lasting throughout the whole lactation period.

As predicted, temporarily crated sows utilised the slope wall less frequently than permanently crated sows once the crate was opened. We could, however, see, that sows still prefer some kind of support while lying down, and this emphasizes the persisting need for a pen design which would provide the safety for the piglets and satisfy sows' needs while increasing their welfare. Moreover, we predicted that sows would try to increase their contact with piglets by utilising lying down locations in the pen that are in proximity to the nest area once it is occupied with the majority of the piglets. Although expected, this behaviour was not often observed.

In our experiment, the housing system had no significant effect on the piglet weight. Further research is required in this area because piglet weight gain is one of the key aspects about which the farmers are concerned.

No fatal trapping events were observed during our experiment. These results suggest that opening of a farrowing crate on day 4 post-partum and allowing sows free movement in a pen does not pose risk to piglets.

In conclusion, although opening of a hinged farrowing crate significantly affects the number of postural changes performed by sows in temporary crating, it does not threaten the safety of piglets. The increased number of postural changes in combination with the different frequency in the use of the slope wall or other support during lying down did not affect the number of piglet trapping events or fatal piglet trapping events. Therefore, we conclude that temporary crating could represent the future of pig husbandry, because it combines the requirements of farmers with the opportunity for sows to express their natural behaviour more freely and as a result improves their as well as their piglets' welfare.

8 Bibliography

Algers B, Jensen P. 1985. Communication during suckling in the domestic pig. effects of continuous noise. Applied Animal Behaviour Science **14**:49–61.

Algers B, Jensen P. 1991. Teat stimulation and milk production during early lactation in sows: Effects of continuous noise. Canadian Journal of Animal Science **71**:51–60.

Allwin B, Swaminathan R. 2016. The wild pig (sus scrofa) behavior – a retrospective study. Journal of Veterinary Science & Technology **7.**

Andersen IL, Nævdal E, Bøe KE. 2011. Maternal investment, sibling competition, and offspring survival with increasing litter size and parity in pigs (sus scrofa). Behavioral Ecology and Sociobiology **65**:1159–1167.

Andersen IL, Vasdal G, Pedersen LJ. 2014. Nest building and posture changes and activity budget of gilts housed in pens and crates. Applied Animal Behaviour Science **159**:29–33.

Appleby MC, Weary DM, Taylor AA, Illmann G. 1999. Vocal communication in pigs: Who are nursing piglets screaming at? Ethology **105**:881–892.

Baxter EM, Andersen IL, Edwards SA. 2018. Sow welfare in the farrowing crate and alternatives. Advances in Pig Welfare:27–72.

Baxter EM, Lawrence AB, Edwards SA. 2011. Alternative farrowing systems: Design criteria for farrowing systems based on the biological needs of sows and piglets. Animal **5**:580-600.

Berensmann I, Klein S, Reese S, Erhard M, Patzkéwitsch D. 2018. Ein Vergleich Verschiedener Abferkelsysteme. Tierärztliche Praxis Ausgabe G: Großtiere / Nutztiere **46**:291–297.

Blackshaw JK, Hagelsø AM. 1990. Getting-up and lying-down behaviours of loose-housed sows and social contacts between sows and piglets during day 1 and Day 8 after parturition. Applied Animal Behaviour Science **25**:61–70.

Bradshaw RH, Broom DM. 1999. A comparison of the behaviour and performance of sows and piglets in crates and oval pens. Animal Science **69**:327–333.

Bunger B. 1985. Ethological Method for Assessment of Vitality of Newborn Piglets. Monatshefte Fur Veterinarmedizin **40**: 519-24.

Caille ME, Meunier-SAlaün MC, Ramonet Y. 2010, Sows in loose farrowing system effects on performance and work conditions. Swine Days Res. 9-13.

Caliebe A, Nebel A, Makarewicz C, Krawczak M, Krause-Kyora B. 2017. Insights into early pig domestication provided by ancient DNA analysis. Scientific Reports **7**.

Castrén H, Algers B, de Passillé A-M, Rushen J, Uvnäs-Moberg K. 1993. Preparturient variation in progesterone, prolactin, oxytocin and somatostatin in relation to nest building in sows. Applied Animal Behaviour Science **38**:91–102.

Ceballos MC, Góis KC, Parsons TD. 2020. The opening of a hinged farrowing crate improves lactating sows' welfare. Applied Animal Behaviour Science **230**:105068.

Ceballos MC, Rocha Góis KC, Parsons TD, Pierdon M. 2021. Impact of duration of farrowing crate closure on physical indicators of sow welfare and piglet mortality. Animals **11**:969.

Chaloupková H, Illmann G, Pedersen LJ, Malmkvist J, Šimečková M. 2008. Sow responsiveness to human contacts and piglet vocalization during 24H after onset of parturition. Applied Animal Behaviour Science **112**:260–269.

Chapel N, Lucas J, Radcliffe S, Stewart K, Lay D. 2018. Comparison of vocalization patterns in piglets which were crushed to those which underwent human restraint. Animals **8**:138.

Chen C et al. 2008. Maternal infanticide in sows: Incidence and behavioural comparisons between savaging and non-savaging sows at parturition. Applied Animal Behaviour Science **109**:238–248.

Chidgey KL, Morel PCH, Stafford KJ, Barugh IW. 2015. Sow and piglet productivity and sow reproductive performance in farrowing pens with temporary crating or farrowing crates on a commercial New Zealand pig farm. Livestock Science **173**:87–94.

Chidgey KL, Morel PCH, Stafford KJ, Barugh IW. 2016. The performance and behaviour of gilts and their piglets is influenced by whether they were born and reared in farrowing crates or farrowing pens. Livestock Science **193**:51–57.

Chidgey KL, Morel PCH, Stafford KJ, Barugh IW. 2017. Sow and piglet behavioral associations in farrowing pens with temporary crating and in farrowing crates. Journal of Veterinary Behavior **20**:91–101.

Choi Y, Min Y, Kim Y, Jeong Y, Kim D, Kim J, Jung H. 2020. Effects of loose farrowing facilities on reproductive performance in primiparous sows. Journal of Animal Science and Technology **62**:218–226.

Condous PC, Plush KJ, Tilbrook AJ, van Wettere WH. 2016. Reducing sow confinement during farrowing and in early lactation increases piglet mortality1. Journal of Animal Science **94**:3022–3029.

Damm BI, Friggens NC, Nielsen J, Ingvartsen KL, Pedersen LJ. 2002. Factors affecting the transfer of porcine parvovirus antibodies from sow to piglets. Journal of Veterinary Medicine Series A **49**:487–495.

Damm BI, Lisborg L, Vestergaard KS, Vanicek J. 2003. Nest-building, behavioural disturbances and heart rate in farrowing sows kept in crates and Schmid Pens. Livestock Production Science **80**:175–187.

Damm BI, Moustsen V, Jørgensen E, Pedersen LJ, Heiskanen T, Forkman B. 2006. Sow preferences for walls to lean against when lying down. Applied Animal Behaviour Science **99**:53–63.

De Passillé A-M, Rushen J, Hartsock T. 1988. Ontogeny of Teat Fidelity in pigs and its relation to competition at suckling. Canadian Journal of Animal Science **68**:325–338.

Edwards, SA, Fraser, D. 1997. Housing systems for farrowing and lactation. The Pig Journal **39**: 77–89.

Farmer C, Devillers N, Widowski T, Massé D. 2006. Impacts of a modified farrowing pen design on sow and litter performances and air quality during two seasons. Livestock Science **104**:303–312.

Fraser D. 1980. A review of the behavioural mechanism of milk ejection of the domestic pig. Applied Animal Ethology **6**:247–255.

Gabor TM, Hellgren EC, Bussche RA, Silvy NJ. 1999. Demography, sociospatial behaviour and genetics of feral pigs (*sus scrofa*) in a semi-arid environment. Journal of Zoology **247**:311–322.

Goumon S, Illmann G, Moustsen V, Baxter E, Edwards S. 2022. Review of temporary crating of Farrowing and lactating sows. Frontiers in Veterinary Science **9**.

Goumon S, Leszkowová I, Šimečková M, Illmann G. 2018. Sow stress levels and behavior and piglet performances in farrowing crates and farrowing pens with temporary crating1. Journal of Animal Science **96**:4571–4578.

Grimberg-Henrici CGE, Czycholl I, Burfeind O, Krieter J. 2017. What do maternal tests actually test? Applied Animal Behaviour Science **189**:23–28.

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

Gustafsson M, Jensen P, de Jonge FH, Illmann G, Spinka M. 1999. Maternal behaviour of domestic sows and crosses between domestic sows and wild boar. Applied Animal Behaviour Science **65**:29–42.

Hales J, Moustsen VA, Nielsen MB, Hansen CF. 2015. Temporary confinement of loose-housed hyperprolific sows reduces piglet mortality1. Journal of Animal Science **93**:4079–4088.

Hales J, Moustsen VA, Nielsen MBF, Hansen CF. 2016. The effect of temporary confinement of hyperprolific sows in sow welfare and piglet protection pens on sow behaviour and salivary cortisol concentrations. Applied Animal Behaviour Science **183**:19–27.

Hanson RP, Karstad L. 1959. Feral swine in the southeastern United States. The Journal of Wildlife Management **23**:64.

Hartmann PE, Smith NA, Thompson MJ, Wakeford CM, Arthur PG. 1997. The lactation cycle in the sow: Physiological and management contradictions. Livestock Production Science **50**:75–87.

Hartsock TG, Barczewski RA. 1997. Prepartum behavior in swine: Effects of pen size. Journal of Animal Science **75**:2899.

Hemsworth PH, Winfield CG, Mullaney PD. 1976. A study of the development of the Teat Order in Piglets. Applied Animal Ethology **2**:225–233.

Hoai Nam N, Sukon P. 2020. Associated factors for farrowing duration in sows with natural parturition in intensive conditions. Journal of World's Poultry Research **10**:320–324.

Höbel C, Patzkéwitsch D, Reese S, Erhard M, Klein S. 2018. Ein Vergleich Verschiedener Abferkelsysteme. Tierärztliche Praxis Ausgabe G: Großtiere / Nutztiere **46**:357–367.

Illmann G, Goumon S, Chaloupková H. 2021. Assessment of lying down behaviour in temporarily crated lactating sows. animal **15**:100130.

Illmann G, Goumon S, Šimečková M, Leszkowová I. 2019. Effect of crate opening from day 3 postpartum to weaning on nursing and suckling behaviour in domestic pigs. Animal **13**:2018–2024.

Illmann G, Hammerschmidt K, Špinka M, Tallet C. 2013. Calling by domestic piglets during simulated crushing and isolation: A signal of need? PLoS ONE **8**.

Illmann G, Madlafousek J. 1995. Occurrence and characteristics of unsuccessful nursings in minipigs during the first week of life. Applied Animal Behaviour Science **44**:9–18.

Illmann G, Neuhauserová K, Pokorná Z, Chaloupková H, Šimečková M. 2008. Maternal responsiveness of sows towards piglet's screams during the first 24H postpartum. Applied Animal Behaviour Science **112**:248–259.

Illmann G, Špinka M, Štětková Z. 1999. Predictability of nursings without milk ejection in domestic pigs. Applied Animal Behaviour Science **61**:303–311.

Jarvis S, Calvert SK, Stevenson J, vanLeeuwen N, Lawrence AB. 2002. Pituitary-adrenal activation in pre-parturient pigs *(sus scrofa)* is associated with behavioural restriction due to lack of space rather than nesting substrate. Animal Welfare **11**:371–384.

Jarvis S, McLean KA, Calvert SK, Deans LA, Chirnside J, Lawrence AB. 1999. The responsiveness of sows to their piglets in relation to the length of parturition and the involvement of endogenous opioids. Applied Animal Behaviour Science **63**:195–207.

Jarvis S, Van der Vegt BJ, Lawrence AB, McLean KA, Deans LA, Chirnside J, Calvert SK. 2001. The effect of parity and environmental restriction on behavioural and physiological responses of pre-parturient pigs. Applied Animal Behaviour Science **71**:203–216.

Jensen P. 1986. Observations on the maternal behaviour of free-ranging domestic pigs. Applied Animal Behaviour Science **16**:131–142.

Jensen P. 1988. Maternal behaviour and mother—young interactions during lactation in free-ranging domestic pigs. Applied Animal Behaviour Science **20**:297–308.

Jensen P, Gustafsson M, Augustsson H. 1998. Teat massage after milk ingestion in domestic piglets: An example of honest begging? Animal Behaviour **55**:779–786.

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

Jensen P, Redbo I. 1987. Behaviour during nest leaving in free-ranging domestic pigs. Applied Animal Behaviour Science **18**:355–362.

Johnson AK, Marchant-Forde JN. 2009. Welfare of Pigs in the farrowing environment. The Welfare of Pigs:141–188.

Jones JET. 1966. Observations on parturition in the sow: Part II: The parturient and Post-Parturient Phases. British Veterinary Journal **122**:471–478.

KilBride AL, Mendl M, Statham P, Held S, Harris M, Cooper S, Green LE. 2012. A cohort study of preweaning piglet mortality and farrowing accommodation on 112 commercial pig farms in England. Preventive Veterinary Medicine **104**:281–291.

Kinane O, Butler F, O'Driscoll K. 2021. Freedom to grow: Improving sow welfare also benefits piglets. Animals **11**:1181.

King RL, Baxter EM, Matheson SM, Edwards SA. 2019. Temporary crate opening procedure affects immediate post-opening piglet mortality and sow behaviour. Animal **13**:189–197.

King RH, Mullan BP, Dunshea FR, Dove H. 1997. The influence of piglet body weight on milk production of sows. Livestock Production Science **47**:169–174.

Klobasa F, Werhahn E, Butler JE. 1987. Composition of sow milk during lactation. Journal of Animal Science **64**:1458–1466.

Lambertz C, Petig M, Elkmann A, Gauly M. 2015. Confinement of sows for different periods during lactation: Effects on behaviour and lesions of sows and performance of piglets. Animal **9**:1373–1378.

Lawrence AB, Petherick JC, McLean KA, Deans LA, Chirnside J, Gaughan A, Clutton E, Terlouw EMC. 1994. The effect of environment on behaviour, plasma cortisol and prolactin in parturient sows. Applied Animal Behaviour Science **39**:313–330.

Loftus L, Bell G, Padmore E, Atkinson S, Henworth A, Hoyle M. 2020. The effect of two different farrowing systems on sow behaviour, and piglet behaviour, mortality and growth. Applied Animal Behaviour Science **232**:105102.

Lohmeier RY, Gimberg-Henrici CGE, Burfeind O, Krieter J. 2019. Suckling behaviour and health parameters of sows and piglets in free-farrowing pens. Applied Animal Behaviour Science **211**:25–32.

Mack LA, Rossini SP, Leventhal SJ, Parsons TD. 2017. C ASE S tudy : Differences in social behaviors and mortality among piglets housed in alternative lactational systems. The Professional Animal Scientist **33**:261–275.

Marchant JN, Broom DM, Corning S. 2001. The influence of sow behaviour on piglet mortality due to crushing in an open farrowing system. Animal Science **72**:19–28.

Marchant JN, Rudd AR, Mendl MT, Broom DM, Meredith MJ, Corning S, Simmins PH. 2000. Timing and causes of piglet mortality in alternative and conventional farrowing systems. Veterinary Record **147**:209–214.

Marchant-Forde JN. 2002. Piglet- and Stockperson-directed sow aggression after farrowing and the relationship with a pre-farrowing, human approach test. Applied Animal Behaviour Science **75**:115–132.

Mason SP, Jarvis S, Lawrence AB. 2003. Individual differences in responses of piglets to weaning at different ages. Applied Animal Behaviour Science **80**:117–132.

McBride G. 1963. The "Teat Order" and Communication in young pigs. Animal Behaviour **11**:53–56.

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

Melišová M, Illmann G, Chaloupková H, Bozděchová B. 2014. Sow postural changes, responsiveness to piglet screams, and their impact on piglet mortality in pens and CRATES1,2. Journal of Animal Science **92**:3064–3072.

Morgan L, Meyer J, Novak S, Younis A, Ahmad WA, Raz T. 2021. Shortening sow restraint period during lactation improves production and decreases hair cortisol concentrations in sows and their piglets. animal **15**:100082.

Moustsen VA, Hales J, Lahrmann HP, Weber PM, Hansen CF. 2013. Confinement of lactating sows in crates for 4 days after farrowing reduces piglet mortality. Animal **7**:648–654.

Newberry RC, Wood-Gush DGM. 1985. The suckling behaviour of domestic pigs in a semi-natural environment. Behaviour **95**:11–25.

Nicolaisen T, Lühken E, Volkmann N, Rohn K, Kemper N, Fels M. 2019. The effect of sows' and piglets' behaviour on piglet crushing patterns in two different farrowing pen systems. Animals **9**:538.

Nowland TL, van Wettere WH, Plush KJ. 2019. Allowing sows to farrow unconfined has positive implications for sow and piglet welfare. Applied Animal Behaviour Science **221**:104872.

Ocepek M, Andersen IL. 2018. Sow communication with piglets while being active is a good predictor of maternal skills, piglet survival and litter quality in three different breeds of domestic pigs (sus scrofa domesticus). PLOS ONE **13**.

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

Olsson A-C, Botermans J, Englund J-E. 2018. Piglet mortality – a parallel comparison between loose-housed and temporarily confined farrowing sows in the same herd. Acta Agriculturae Scandinavica, Section A — Animal Science **68**:52–62.

Oostindjer M, Bolhuis JE, Mendl M, Held S, Gerrits W, van den Brand H, Kemp B. 2010. Effects of environmental enrichment and loose housing of lactating sows on piglet performance before and after WEANING1. Journal of Animal Science **88**:3554–3562.

Pedersen LJ, Damm BI, Marchant-Forde JN, Jensen KH. 2003. Effects of feed-back from the nest on maternal responsiveness and postural changes in primiparous sows during the first 24 h after farrowing onset. Applied Animal Behaviour Science **83**:109–124.

Pedersen ML, Moustsen VA, Nielsen MBF, Kristensen AR. 2011. Improved udder access prolongs duration of milk letdown and increases piglet weight gain. Livestock Science **140**:253–261.

Plush KJ, McKenny LA, Nowland TL, van Wettere WHEJ. 2021. The effect of Hessian and straw as nesting materials on sow behaviour and piglet survival and growth to weaning. Animal **15**:100273.

Poteaux C, Baubet E, Kaminski G, Brandt S, Dobson FS, Baudoin C. 2009. Socio-genetic structure and mating system of a wild boar population. Journal of Zoology **278**:116–125.

Salaün C, Le Roux N, Vieuille C, Meunier-Salaün MC, Ramonet Y. 2004. Effect of housing system on lactating sows and piglets behaviour and on their performances before weaning.Swine days Res. **36**:371–8.

Sasaki Y, Koketsu Y. 2007. Variability and repeatability in gestation length related to litter performance in female pigs on Commercial Farms. Theriogenology **68**:123–127.

Singh C, Verdon M, Cronin GM, Hemsworth PH. 2017. The behaviour and welfare of sows and piglets in farrowing crates or lactation pens. Animal **11**:1210–1221.

Skok J, Škorjanc D. 2013. Formation of Teat Order and estimation of piglets' distribution along the mammary complex using mid-domain effect (MDE) model. Applied Animal Behaviour Science **144**:39–45.

Skok J, Škorjanc D. 2014. Group suckling cohesion as a prelude to the formation of Teat Order in Piglets. Applied Animal Behaviour Science **154**:15–21.

Spindler E, Klein S, Reese S, Patzkéwitsch D, Erhard M. 2018. Eine alternative abferkelbucht im Feldversuch – direkter Vergleich Zweier Abferkelsysteme. Tierärztliche Praxis Ausgabe G: Großtiere / Nutztiere **46**:283–290.

Špinka M, Algers B. 1995. Functional view on udder massage after milk let-down in Pigs. Applied Animal Behaviour Science **43**:197–212.

Špinka M, Illmann G, de Jonge F, Andersson M, Schuurman T, Jensen P. 2000. Dimensions of maternal behaviour characteristics in domestic and wild×domestic crossbred sows. Applied Animal Behaviour Science **70**:99–114.

Thodberg K, Jensen KH, Herskin MS. 2002. Nursing behaviour, postpartum activity and reactivity in sows. Applied Animal Behaviour Science **77**:53–76.

Valros A, Rundgren M, Špinka M, Saloniemi H, Algers B. 2003. Sow activity level, frequency of standing-to-lying posture changes and anti-crushing behaviour—within sow-repeatability and interactions with nursing behaviour and piglet performance. Applied Animal Behaviour Science **83**:29–40.

Van Dijk AJ, van Rens BTTM, van der Lende T, Taverne MAM. 2005. Factors affecting duration of the expulsive stage of parturition and piglet birth intervals in sows with uncomplicated, spontaneous farrowings. Theriogenology **64**:1573–1590.

Verhovsek D, Troxler J, Baumgartner J. 2007. Peripartal behaviour and teat lesions of sows in farrowing crates and in a loose-housing system. Animal Welfare **16**:273–276.

Walls A, Hatze B, Lomax S, Bathgate R. 2022. Defining "normal" in pig Parturition. Animals **12**:2754.

Weary DM, Fraser D. 1995. Calling by domestic piglets: Reliable signals of need? Animal Behaviour **50**:1047–1055.

Weary DM, Lawson GL, Thompson BK. 1996a. Sows show stronger responses to isolation calls of piglets associated with greater levels of Piglet need. Animal Behaviour **52**:1247–1253.

Weary DM, Pajor EA, Fraser D, Honkanen A-M. 1996b. Sow body movements that crush piglets: A comparison between two types of farrowing accommodation. Applied Animal Behaviour Science **49**:149–158.

Whittemore CT, Fraser D. 1974. The nursing and suckling behaviour of pigs. II. vocalization of the sow in relation to suckling behaviour and milk ejection. British Veterinary Journal **130**:346–356.

Wischner D, Kemper N, Krieter J. 2009. Nest-building behaviour in sows and consequences for pig husbandry. Livestock Science **124**:1–8.

Wischner D, Kemper N, Stamer E, Hellbrügge B, Presuhn U, Krieter J. 2010. Pre-lying behaviour patterns in confined sows and their effects on crushing of Piglets. Applied Animal Behaviour Science **122**:21–27.

Yun J, Li C, Chung H, Choi J, Cho M. 2015. Predicting photoisomerization profile of the highly polymerized nematic Azobenzene Liquid Crystal Network: First principle calculation. Chemical Physics Letters **627**:20–25.

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