SOWS’ MATERNAL BEHAVIOUR AS A MAJOR INFLUENCE ON THE SURVIVAL OF PIGLETS

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GENERAL INTRODUCTION

Piglet mortality is the key factor in sow reproduction and the basis for economically successful piglet rearing. However, measures applied in sow management often represent a challenge with regard to animal welfare. Up to 15% of piglets born alive may die before weaning (Blackshaw et al., 1994). A large proportion of piglets’ pre-weaning deaths occur during farrowing and in the first 48 h after parturition (Barnett et al., 2001). Crushed piglets represent one of the most important factors limiting sow productivity and are also a great obstacle in any attempt to improve animal welfare (Arey and Sancha, 1996). The risk of crushing by the sow is associated with the proximity between the dam and her offspring necessary for adequate colostrum intake and the provision of warmth within the first few days after birth (Cronin and Smith, 1992). Grandinson (2005) described the maternal behaviour of sows as an important component of maternal success, increasing the welfare of both the piglets and the sow and improving the survivability of the offspring. One aim of the traditional farrowing crate has been the restriction of the sow’s movement patterns in order to reduce pre-weaning mortality, and crushing in particular (Edwards and Fraser, 1997). The restraint nature of the crate decreased the responsibility of the sows to take care of their offspring (Andersen et al., 2005).

The aim of this thesis was to investigate the behavioural background of different traits to characterise the maternal behaviour of crated sows, in particular the locomotory behavioural pattern, in relationship to crushing piglets. All traits were recorded by video on one farm in order to reduce environmental influences.

The first chapter provides a review of the ‘nest-building’ behaviour of sows because prepartal behaviour of sows is mainly characterised by ‘nest-building’ activities. ‘Nest-building’ behaviour does not significantly change due to domestication and remains part of the natural behaviour pattern in different housing systems. Possibilities to perform this behaviour in different housing systems, considering the increased demands for animal welfare, were discussed.

In the second chapter, the posture patterns of sows are analysed in relationship to crushing piglets. The frequency, the duration and the manner of different movement patterns of important pre- and post-farrowing behaviour are investigated to determine differences in
maternal protectiveness of sows that had crushed piglets or sows that had not crushed any piglet.

The **third chapter** focuses on components of ‘pre-lying’ behaviour of sows and the relation to crushing piglets. The individual responsiveness of sows is evaluated by the analysis of various behavioural patterns indicating the interaction between the sow and the piglets with regard to critical movements and piglet activity.

The **fourth chapter** presents behavioural tests and their relationship to the locomotory behaviour of sows. Differences in posture patterns and maternal protectiveness were assessed by tests and recorded by video in the study in order to develop behavioural traits that indicate the sow’s mothering ability.

**References**


CHAPTER ONE

Nest-building behaviour in sows and consequences for pig husbandry

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Abstract
Patterns of maternal behaviour are strongly related to reproductive abilities in sows. Prepartal behaviour of sows is mainly characterised by nest-building activities, resulting in a nest that provides shelter for the piglets. In the course of domestication, sows have not lost their instinctive behaviour to nest-build, but perform at least elements of it when appropriate space and materials are available. The onset and performance of nest-building is both stimulated internally via hormones and externally via feedback from the environment. With this environmental influence, the possibilities to perform nest-building can be restricted to different extents in commercially farmed pigs. The aim of the present review is to point out the sow’s need for nest-building performance as part of the natural behaviour pattern, although they are kept in different modern housing systems. With regard to increased demands for animal welfare and following changes in the legislation for pig husbandry, possible consequences for different housing systems are discussed.

Keywords
Reproduction; Crates; Maternal behaviour; Piglets; Pens

1. Introduction
In modern pig husbandry, the ability of the sow to raise large litters and to meet the piglets’ needs especially with regard to milk provision is essential. To reduce piglet losses and to facilitate human intervention, farrowing crates have been developed. In comparison to alternatives systems like pens, farrowing crates restrain the sow’s movements during parturition and lactation and have mainly been intended to protect piglets from being crushed (Robertson et al., 1966; Edwards and Fraser, 1997). With this restriction, the performance of typical reproductive behaviour like an increased activity one to two days before farrowing (Jensen 1986), as seen in free-ranging sows, is limited in commercially farmed pigs. One important behavioural trait before the onset of parturition is nest-building as well in domesticated, feral and wild sows. Nest-building behaviour is specific and unique in members of the family Suidae, including the pig (Sus scrofa) (Lent, 1974). This behavioural pattern characterises the pig as ‘hiders’ (Lent, 1974), or more specifically as ‘nest dwellers’ (Stangel and Jensen, 1991). Nest-building is performed to provide the offspring with shelter and comfort, particularly with respect to thermoregulation. Due to a lack of brown fat tissue, the piglets demand an increased surrounding temperature (Myrcha and Jezierski, 1972; Varley and Stedmann, 1994). Their physiological thermoregulation is still developing, particularly
during the first two weeks (Hurnik, 1985). Moreover, compared to other even-toed ungulates, piglets are rarely born with hair, and have an unfavourable surface-weight proportion, weighing less than 1% of their adult weights (Mayer et al., 2002). Thermoregulation is closely related to birth weight. The maintenance of the homeothermic balance in the cold is reduced in smaller piglets due to the greater surface to body mass ratio resulting in higher heat losses (Herpin et al., 2002). Without protection against climatic influences, the piglets would cool down and die. By providing a microclimate with protection against other weather effects, the nest supports the new-born piglet to perform thermoregulation and to limit rapid heat loss (Briedermann, 1986). Moreover, it offers protection against weather and predators (Pullar, 1953). In addition, piglets are kept close to the sow and away from the family group. In this way, it is ensured that the piglets are not trampled by other adults and that other piglets do not steal milk from the sow (Jensen, 1986).

Regarding the duration of staying in the nest, the classification of piglets as altricial or precocial animals is discussed controversially. Fraser (1980) classified them as precocial animals, even though they are born in large litters and spend their first days of life in the nest. On the contrary, the classification as altricial animals is justified by the long period up to seven days spent in the nest (Jensen and Redbo, 1987). This is also indicated by the fact that no rapid individual bonds with the offspring are performed, as this is not essential for nesting animals (Kilgour, 1985). Sows usually do not lick the newborn or sever the umbilical cord (Randall, 1972; Fraser, 1984) and are passive during farrowing until the last piglet is born (Stangel and Jensen, 1991). On the contrary, Stangel and Jensen (1991) reported cases of sows cleaning their piglets and consuming their afterbirths. To compound the oppositional views, Portmann (1960) suggested the term ‘secondary precocial’ to describe the piglets’ behaviour.

In the course of domestication and the associated reduced variability of the environment, sows have lost the need for protection against climatic influences, starvation and predators, as stated by Lindsay (1985). However, this position ignores the fact that extensive farming with free-roaming, domesticated animals is practised in many countries, still exposing them to various influences. Even though the influences of domestication on some behaviour patterns can not be denied, sows in extensive housing still show behaviour more or less identical with that of wild boars when nesting material and sites are provided (Gustafsson et al., 1999). This paper reviews the pre-farrowing nest-building behaviour of sows in different housing systems and the possible consequences for pig husbandry.
2. Nest-building behaviour under natural or semi-natural environments

Both genders build and use modified nests and beds for resting and loafing (Martys, 1982). Therefore, it is possible to divide nests into sleeping nests, ‘mock’ nests (Jensen, 1986) and farrowing nests (Pfeffer, 1959), but only the latter are the object of this review.

In general, pigs investigate their surroundings by rooting, sniffing, biting and chewing on digestible and also indigestible items (Studnitz et al., 2007). Nest-building is a modification of this behaviour with the aim to build a nest as shelter. It is a pre-defined, inherited behavioural fixed action pattern shown both in male and female pigs (Eibl-Eibesfeldt, 1963). Nest-building behaviour of mammals represents an innate behaviour. Sign stimuli are necessary to perform this behaviour pattern. They represent an important starting point for the behaviour chain, determining and controlling the behaviour patterns ante and post partum, including the care of the offspring (Buß, 1972). It is shown as well in inexperienced as in experienced animals and does not have to be learnt (Lorenz, 1937). However, sows can learn how to build a better nest and improve by experience with each litter (Jensen et al., 1987).

Grandin and Deesing (1998) describe nest-building in sows as an example of the interaction between instinct and learning. Age or experience modifies nest-building behaviour (Jensen, 1989) as well as the interaction with the farrowing environment (Thodberg et al., 1999). Already at an age of six days, piglets perform basic elements of nest-building behaviour (Gundlach, 1968). In experiments, isolated piglets perform nest-building behaviour earlier to maintain their thermoregulation (Gundlach, 1968).

Nest-building behaviour is one important part in the whole process of pre and post partum maternal behaviour. During the total life-span of a sow, pre-farrowing nest-building behaviour is only performed a few times with each new pregnancy and parturition to come. Under natural conditions, the sow limits her scope of action to a smaller home range within the last month of pregnancy and shows reduced activity (Kurz and Marchinton, 1972). One to three days prior to parturition the sow separates from the group and becomes solitary, exploring her surroundings for a suitable place to build the nest (Hafez et al., 1962; Buß, 1972; Jensen, 1986; Stolba and Wood-Gush, 1989). The sow travels distances up to 6.5 km within 6 hours and stops at several places to explore the ground by sniffing and rooting (Jensen, 1986). Compared to grass areas, forest or forest border habitats are preferred as nestsites (Stolba and Wood-Gush, 1984). Favoured sites are often situated below a slope and characterised by offering shelter against rain and wind, for instance under dense vegetation, probably in the form of a roof of branches hanging down (Gundlach, 1968; Frädrich, 1974, Stolba and Wood-Gush, 1984). These places allow an open view and provide cover on two
sides (Stolba and Wood-Gush, 1984). The ground is often well-drained soil and easy to root (Jensen, 1986). Jensen (1986) reported in free-ranging sows the occurrences of ‘mock nests’. These nests were built up like farrowing nests, but they were not used. A change in temperament towards unpredictable aggression, even against their own previous progeny, can be observed (Graves, 1984) as well as increased restlessness (Jones, 1966). Experienced mothers seem to be calmer than primiparae (Signoret et al., 1975). Baxter (1982) also reported fearfulness or agitation in gilts rather than in experienced sows.

Generally, the sow starts to build the nest at approximately 24 h before parturition, showing most intensive activity 12 to 6 h before farrowing (Jensen, 1989; Cronin et al., 1994; Haskell and Hutson, 1994; Algers and Uvnäs-Moberg, 2007). Nest-building in wild boars as well as in domestic sows can be roughly classified in two consecutive phases: initially, in the first phase, the ground is rooted and pawed and a shallow hole is dug. In the second phase, the sow collects, carries and arranges the nest material along the edges of and in the nest (Jensen, 1993). In more detail, the sow roots and digs the ground by throwing the soil with her mouth and head (Gundlach, 1968). She gathers nest-building material, mainly consisting of branches, bushes and other organic material, from within a radius of 20 m (Mayer et al., 2002) and 50 m around the nest (Gundlach, 1968). The gathered material includes dry grass and leaves (Gundlach, 1968), as well as fern and moss (Snethlage, 1967).

Younger and smaller sows have a smaller radius for gathering compared to older and larger sows (Jensen, 1989; Mayer et al., 2002). Gathering is performed by breaking and biting of the material, shuffling it in the mouth and carrying it to the nest site. The sow deposits the material along the edges of the nest and, by turning her body round in circles with repeated pawing and pressing her head against the material, the edges of the nest are distinctly elevated (Gundlach, 1968). The sow fills the nest with further material by throwing smaller parts with head turns in the middle of the nest and distributes them by turning around herself. Stabilisation of the whole nest is achieved by integrating thick branches and twigs, which partially protrude over the side of the nest. After covering with finer material, such as grass, leaves and small twigs, the nest shows a stratified structure with a loose grass heap up to one metre high and includes smaller and larger wooden parts (Gundlach, 1968).

In the finished nest, the sow keeps the material together by pawing and pushing it back with her snout. In this way, sows gradually construct an oval nest with positively correlated length and width (Mayer et al., 2002). In few cases, dome-like nest coverings have been reported (Briedermann, 1986). The sow usually leaves the nest at a certain side, and sometimes covers the nest with more material before leaving on foraging trips (Tisdell, 1982).
2.1. Influences on nest-building performance

Nest-building behaviour is both influenced by internal and external stimuli. The appropriate combination of all modulating endogenous and exogenous stimuli decides whether complete and successful nest-building will take place. With regard to these influencing stimuli, two nest-building behaviour elements can be distinguished. The initial phase of site searching and hole digging is regulated by internal hormonal changes, while the second, material-oriented phase is mainly dependent on external stimuli such as feedback from the nest site (Jensen, 1993). Hutson (1988) indicated that a successful completion of each phase is the stimulus for the next phase, like a chain or cascade of response.

Several stimuli are discussed as the starting point of this chain in the first phase. For instance, Gilbert et al. (2001) suggested that some sort of signal, resulting from foetal maturation, might initiate the cascade for nest-building behaviour. In more detail, the hormonal impact on maternal behaviour in pigs was reported by Algers and Uvnäs-Moberg (2007). In short, the onset of nest-building seems to be triggered by a rise in prolactin level (Widowski et al., 1990; Castrén et al., 1993). This rise itself is induced by a decrease in progesterone and an increase in prostaglandin (Ellendorff et al., 1979; Burne et al., 2001b; Algers and Uvnäs-Moberg, 2007). Nest-building behaviour can be induced by the administration of prostaglandin PGF$_2$α injections in pregnant sows (Widowski and Curtis, 1989). On the contrary, injection of the prostaglandin synthesis inhibitor indomethacin to late pregnant gilts reduces nest-building behaviour (Gilbert et al., 2001). The cessation of nest-building has been suggested to be strongly correlated with the dramatic rise in oxytocin levels 4 h prior to parturition (Castrén et al. 1993). Whether the effect of oxytocin, leading to frequent uterine contractions (Gilbert et al., 1994), stops nest-building or whether oxytocin induces the cessation at a central level still remains unknown (Algers and Uvnäs-Moberg, 2007).

The second phase, depending on external stimuli, is termed as the material-oriented phase (Jensen 1988a). To continue the reaction chain, the sow is reliant on feedback and external stimuli. Stimuli are provided by proper nest material and therefore the availability of suitable nest material is crucial. This provision again is strongly determined by the material’s suitability to stake, stuff and protect (Arey et al., 1991). The more suitable the material, the sooner nest-building is completed. For example, with access to branches, gilts terminate their nest-building sooner than without (Damm et al., 2000). Arey et al. (1991) also showed that the environment provided (e.g. provision of pre-formed nests) altered nest-building behaviour. Widowski and Curtis (1990) reported that the behaviour was directed by the nesting material as stimulus but the structure of the nesting material did not affect the activity.
of the sows. Stolba and Wood-Gush (1984) described that ‘high standing stalks’ release the behaviour. Therefore, it can be assumed that the presence of nesting material triggers nest-building behaviour in motivated sows. On the other hand, Hutson (1988) and Blackshaw (1983) claimed that nesting-material is of no importance to sows ante partum. However, Baxter (1983) hypothesised that there is a feedback stimulus to stop nest-building behaviour which was achieved via sufficient ‘udder comfort’ with a comfortable and flexible lying substrate area in the nest.

Habitat and season do not only influence the vegetation and thereby the nesting material, but there is evidence that nest-building behaviour is affected directly by season due to environmental temperatures (Dellmeier and Friend, 1991). The duration and intensity appears to vary with weather conditions and may be observed less frequently during hot summer weather (Damm et al., 2000). With decreasing temperatures, there is a significant increase in rooting and nest-building behaviour (Burne et al., 2001a).

However, external factors are not solely responsible for behavioural patterns in the material-oriented phase; internal, endocrine changes can influence and alter the sensitivity to external stimuli as well (Haskell and Hutson, 1994). For oxytocin, an anti-stress effect promoting calmness and reduced anxiety is described by Uvnäs-Moberg et al. (2001), but the detailed interplay of these factors still has to be investigated.

2.2. Influences of domestication

Buß (1972) described various morphological, physiological and psychological changes in the course of domestication which resulted in behavioural characteristics. Behavioural and other, especially physiological, changes caused by domestication are often based on innate behaviour (Lorenz, 1959). Stressors, such as those usually experienced in the natural environment, are limited in surroundings where locomotion is reduced as food is supplied and protection against predators is given (Lorenz, 1959). Modification of old phylogenetic behavioural elements allows new variances of behavioural patterns, for example, a shortened flight distance. Increased variability in these patterns is reported in domestic animals (Schulz-Scholz, 1963). As a consequence, a possible alteration of nest-building behaviour in domesticated pigs could be assumed. Therefore, the argument that modern sows do not necessarily build nests due to domestication has been used to doubt confinement in farrowing crates (Algers and Uvnäs-Moberg, 2007). These housing systems, established since the late 1950s, were designed to minimise piglet losses by crushing and to improve management (Edwards and Fraser, 1997). Additionally, Grauvogel (1958) postulated that a ‘nest feeling’ is
provided by the enclosed crate and no negative effects on the sows have to be expected. First studies on nest-building behaviour in domestic pigs under semi-natural conditions were investigated in the 1980s (Stolba and Wood Gush, 1989; Jensen, 1986; Algers and Jensen, 1990). Domestic sows, even with experience of four farrowings in confinement, were able to build nests identical to those of wild boars (Gustafsson et al., 1999). This led to the conclusion that domestication has not given rise to any changes in the performance of nest-building behaviour. Due to only few differences between maternal behaviour in wild and domesticated sows, Mignon-Grasteau et al. (2005) suggested that maternal behaviour is relatively robust in pigs. This statement is supported by Jensen (2002) who described similar behaviour patterns for free-ranging sows and wild boars. On the contrary, Price (1999) mentioned behavioural changes associated with the process of domestication. Through selection, inbreeding and genetic drift animals have been domesticated and forced to adapt to the provided housing and management. Given this adaptation, it might be expected that because nest-building is no longer needed, its associated behaviour would have vanished. However, domestication has not given rise to major changes in the performance of nest-building behaviour. This fact clearly underlines how innate this behaviour is, and highlights its importance.

3. Nest-building behaviour in different housing systems

All elements of nest-building are performed by female pigs in their environment as far as possible (Hutson and Haskell, 1990; Jensen and Toates, 1993). In commercially farmed pigs, maternal behaviour is usually strongly restricted (von Borell et al., 2007). In order to reduce piglet losses due to crushing, and to facilitate human intervention, systems to control sow movement were developed and farrowing crates were introduced on a large scale (Fraser and Broom, 1990; Edwards, 2002). Different types and systems have been created since then, but most of them without considering the natural periparturient behaviour of sows (Damm et al., 2003).

3.1. Housing in crates

Farrowing crates and concrete floors prevent much of the nest-building behaviour, but many of the motor elements are still present. In intensive pig production, most exogenous stimuli are excluded and in most cases only provided if regulated by legislation. In confinement, feedback from the nest site, necessary to continue successful nest-building in the material-oriented phase, is and can lead to prolonged, but futile nest-building motivation (Damm et al.,
In general, nest-building-like behaviour is shown, even in absence of exogenous stimuli. However, compared to sows housed in pens, nest-building in crates is performed only in a small variation and in more fragmented and longer phases (Damm et al., 2003). In the crates, animals may grind their teeth, bite and root at the rails and change position frequently between standing and lying (Heck et al., 1988). In comparison to a turn-around crate and an open pen, frequency and duration of standing is greatest in the standard crate and increase gradually until the sow changes position every few minutes (Heck et al., 1988). Sows housed in farrowing crates stand up more often before the onset of parturition compared to sows in pens (Hansen and Curtis, 1980). These activities are accompanied by intermittent grunting, champing of the jaws and increased respiratory rate (Heck et al., 1988). Rooting with the nose and pawing with the front hooves is shown by sows on concrete floor during ‘nest’ preparation (Hartsock and Barczewski, 1997; Thodberg et al., 1999). Heck et al. (1988) and Cronin et al. (1994) reported that crated gilts tended to paw more than gilts in open pens. The sow’s drive to gather nesting material with the mouth results in rooting and mouthing pipes and waterers, as only these items are available for oral manipulation (Hartsock and Barczewski, 1997). In a study dealing with sows in crates and pens, the increase of plasma cortisol as stress indictor in crated sows was related to the interruption of pre-parturient behaviour like nest-building (Lawrence et al., 1997). Pre-partal stress may be coupled with slow parturition and lactation problems (Poe, 1960). Event though the adaption to the behavioural restriction in crates increases from parity to parity, this adaptation has not completely reduced the elevation of stress hormones (Jarvis et al., 2001). Of course it has to be considered that parturition itself influences the release of stress-indicators like cortisol (Lawrence et al., 1994). In general, confined sows show increased activity (Jarvis et al., 2001) and substrate directed-behaviour like interacting with floor and fixtures of the crate (Lawrence et al., 1997). As further possible indicators of stress or frustration, oral or nasal stereotypes are described, such as bar biting (Jensen, 1988b), repetitive pressing of the snout against a surface (Vestergaard, 1984), and straw chewing (Grauvogel, 1958; Horrel et al., 2001). Distinguishing between stereotypes and indirect nest-building behaviour is difficult, since biting and chewing on systemic equipment may be analogous to the act of gathering and carrying branches and twigs to the nest (Jensen, 1993; Hartsock and Baczewski, 1997). Farrowing in crates tends to be more stressful than in pens, even if adaptation to the crate environment occurs (Jarvis et al., 2001). Unsatisfied behavioural needs and idle activities can cause injuries and apparent exhaustion in the sow (Hansen and Curtis, 1980). Additionally, the lack of feedback can result in higher heart rates before farrowing (Jensen and Toates,
Environmental stress of sows inhibits oxytocin and this may compromise the welfare of the sow and the piglet, because oxytocin influences the maternal behaviour (Jarvis et al., 1997). Jarvis et al. (2004) found no relationship between space or substrate and oxytocin, but a positive relationship between oxytocin and unresponsiveness to piglets. Furthermore, Jarvis et al. (2004) described lower levels of oxytocin and higher ACTH concentrations in crated gilts, and these gilts showed more savaging as well as more activity and responsiveness towards their piglets. However, the environment did not affect the cortisol concentration (Jarvis et al., 1998). Ahlstrom (1997) reported a higher responsiveness of crated gilts to their piglets during early stages of farrowing, but a higher probability to savage their piglets. Sows in crates without nest materials have been reported to be less responsive to piglet screams one to three days postpartum (Thodberg et al., 2002a) and vocalise less to piglets on day 1 postpartum in comparison to sows in pens with nest materials (Cronin et al., 1996). On the other hand, Damm et al. (2002) found no effect of the housing environment on the timing of termination of nest-building behaviour during parturition or the course of parturition in gilts.

3.2. Housing in pens

The first study on nest-building behaviour in sows in pens was done by Buß (1972). The phases of nest-building were found to be similar to wild boars (Gundlach, 1968), but restricted by the provision of space and nesting material. In comparison to wild sows, sows housed in pens lack orientation, endurance and purposive directness within their instinctive acts. Explicit exploration behaviour could not be performed and the possibility for digging the hole was not given; therefore these elements were described as ‘degraded behaviour’ because of the lack of exogenous stimuli (Buß, 1972). On the contrary, all observed sows showed an overemphasis in padding out the nest with the straw provided and an exaggerated moving of straw to cover their body (Buß, 1972). In contrast to Hafez et al. (1962), Buß (1972) did not observe the sows cleaning the nest.

Sows housed in pens with straw perform more nest-building behaviour than pigs housed in pens with straw removed (Burne et al., 2000). Sows turn and walk more frequently during 24 hours before farrowing in pens compared to the restricted possible activities in farrowing crates (Hartsock and Barczewski, 1997). Furthermore, Thodberg et al. (2002b) found more elaborated nest-building behaviour in ‘get-away-pens’ in comparison to crates and the pre-partum rooting period started significantly sooner with a longer duration. ‘Nesting-like’ behaviour occurred more frequently in penned than in crated sows (Cronin et al., 1994). Andersen et al. (2005) described significantly more nest-building activity of sows in pens that
had not crushed one single piglet within the first 4 days. Herskin et al. (1998) showed that provision of nest material to loose-housed sows increased the response to piglet screams one to three days postpartum. The provision of space, even without straw, encourages the performance of maternal behaviour during parturition (Jarvis et al. 2004). Against this background, several attempts to develop alternative farrowing accommodation have been made. Although there are several alternative farrowing pens, most of the recent research has been carried out in the ‘Schmid’ or the ‘Werribee farrowing pens’.

Schmid constructed a farrowing pen isolating the sow from other pigs while allowing nest-building behaviour (Schmid, 1991a; Schmid, 1991b). Under Swiss production circumstances, piglet mortality in these pens is comparable to that of farrowing crates (Schmid, 1991a; 1992; 1993). In these so-called ‘Schmid pens’ the duration of nest-building is with 8 h shorter than that in crates with 10.5 h (Damm et al., 2003). Even if the whole period is shorter, sows perform a greater variety of behaviour including more pawing, nodding, collecting, depositing and packing (Damm et al., 2003). Another attempt to offer more possibilities for the expression of nest-building behaviour is the ‘Werribee farrowing pen’ (WFP) (Cronin et al., 1996). This pen is twice as large as a usual crate and consists of two compartments, a ’nest’ and a 'non-nest' area. The width of these pens affects nest-building behaviour, and an appropriately wide WFP is recommended (Cronin et al., 1998).

4. Discussion: consequences for modern sow management

As a major part of reproduction, the sow’s pre-farrowing behaviour is strongly associated with piglet survival because it affects parturition (Heckt et al., 1988; McGlone et al., 1996; Cronin et al., 1993). Explicit nest-building behaviour can clearly be classified as a behavioural need for the pre-partum sow. It is a natural adaptation and even domesticated sows are highly motivated to perform this behaviour pattern. Allowing the sow to perform nest-building, or at least some elements of it, leads to better health and welfare of both the sow and the piglets (Algers, 1994). For instance, increased litter sizes were reported to be positively correlated with more nest-building behaviour (Pedersen et al., 2006). Additionally, a higher responsiveness to piglet distress calls and a lower mortality rate in piglets until weaning is documented in sows with better nest-building performance (Cronin and van Amerongen, 1991). When the opportunity for nest-building is given, the duration of sucking periods is increased and the number of sucking periods terminated by the sow is decreased (Herskin et al., 1998). Therefore, the possibility to perform nest-building behaviour should be offered to all sows in modern management systems. For this possibility, space and the
provision of adequate nest-building material are two relevant pre-requisites. Under confinement, activities that need space like standing or walking can hardly be realized. Denying sows space and material at the time of strong nest-building motivation is associated with negative consequences like reduced piglet survival or savaging of piglets (Hötzel et al., 2005) and results in physiological stress in the sow (Lawrence et al. 1994). With the implementation of the EU Directive 2001/88/EC, this stress might even have increased because all sows have to be loose-housed during the majority of gestation and the subsequent confinement can be a radical change (Boyle et al., 2000). The effects of stress on reproduction are a matter of scientific discussion. While some authors claim that sows are resistant to the effects of single or repeated stressors (Turner et al., 2002; Turner et al., 2005), more commonly it is expected that in pigs experiencing stress, reproduction is negatively affected (Varley and Stedmann, 1994; von Borell, 1995; Einarsson et al., 1996). In this way, a prolonged duration of the farrowing period after restricted nest-building is either caused directly by the less optimal conditions for nest-building or indirectly by the subsequent stress (Vestergaard and Hansen, 1984). The restraint-stillbirth hypothesis, first established by Baxter and Petherick (1980), claimed that the stress caused by the restriction of normal pre-farrowing behaviour in crates induces changes in the endocrine system leading to delayed births and raised stillbirth. On the contrary, Fraser et al. (1997) hypothesised that stimulating the sows’ pre-farrowing activity by pen-mates or human activity results in a lower stillbirth rate and suggested therefore a positive influence of stress towards the sows.

In pens and farrowing huts, the design can improve maternal behaviour and increase the sows’ welfare, which is proposed to lead to a better survival and growth of the piglets (Algers, 1994; Damm et al., 2003). From a holistic point of view, ranking of the motivational effects of internal and external factors of nest-building behaviour is pointless (Jensen and Toates, 1993), but more moves to adapt the present farrowing systems to these behavioural needs are required. Farrowing accommodation restraining the sow’s movements has repeatedly been shown to improve piglet survival (Edwards and Fraser, 1997), but for both economical and ethical reasons these systems require reconsideration (Edwards, 2002). Alternative housings systems resulted in similar piglet mortality rates compared to conventional systems (Weber et al., 2007; Wechsler and Weber, 2007), but the number of crushed piglets was significantly higher in pens with loosed housed sows (Weber et al., 2007). In loose-farrowing systems, piglet’s mortality by crushing can be further reduced by a careful selection of environments and sows showing a genetic determination of positive maternal behaviour (Johnson et al., 2007).
Furthermore, not only space, but the use of nest-building material is restricted in confinement. This restriction results in the sow’s inability to get external stimuli for the performance of nest-building behaviour. As shown, this behaviour is influenced both by internal and external stimuli (Blackshaw, 1983; Jensen, 1988a; Jensen, 1993; Boulton et al., 1997; Burne et al., 1999; Thodeberg et al., 1999). However, mainly external stimuli are crucial to express satisfactory nest-building. The act of nest-building alone is more important than the provision of a nest (Widowski and Curtis 1990). When pre-constructed nests are offered, the sows still show nest-building behaviour (Arey et al., 1991). In crates, sawdust bedding triggers a more active nesting-like ‘behaviour’ before farrowing, but once farrowing has started, sows are more passive (Cronin et al., 1993). This decreases the risk of crushing piglets during farrowing (Thodberg et al., 1999). Furthermore, these sows had a shorter duration of parturition (Cronin et al., 1994), and more piglets born alive, compared to sows that do not receive sawdust bedding (Cronin et al., 1993). McGlone et al. (1996) found that sows housed in farrowing crates with access to a cloth tassel that could be manipulated during the pre-farrowing period, tend to have a reduced incidence of stillbirth. Hötzel et al. (2005) noticed that providing confined sows with enough space and material decreased some of the negative effects of confinement, but did not eliminate them completely.

In the last years, legislation has assessed the welfare benefits of loose-farrowing systems and the implicated positive effects. The intention of several European Commission Directives, such as Directive 2001/88/EC regarding loose-housing, or Directive 2001/93/EC regarding rooting material, is to improve the welfare of pigs, but the sows’ maternal behaviour has not yet been adequately considered in the legislation. In this regard, not only the piglets’ survival, health and welfare have to be taken into account, but also the sows’ health and welfare, including the reproduction performance.

An enriched environment in crates and a greater space for movement are first steps towards the reconsideration and integration of behavioural maternal needs in modern pig management. Therefore, following actions should be put into practice:

(i) in sow management: even though crates might be with no alternative in the following years, all chances to integrate the sows’ behavioural needs should be taken. Under consideration of management, economic, health and hygiene factors, suitable material and space for nest-building-performance should be provided in the pre-partal period.
(ii) in research: alternative pens and nest-building material should be tested in detail with regard to practicability, application and effects on sows and piglets. Individual characteristics of single sows like maternal behaviour should be examined with respect to their genetic determination in order to breed sows better adapted to more open farrowing surroundings (Grandinson et al., 2003, 2005).

(iii) in legislation: results from research should be implemented into consistent EU-Regulations, considering space and material requirements in enriched environments.

Practice, research and legislation together should concentrate on management tools to realise an improvement of the sow’s need for nest-building performance, not only in order to optimise the sows’ health and welfare, but also for the following positive effects on consumer perception and price building.

5. Conclusion
A better understanding of behaviour patterns in general and farrowing behaviour, including nest-building in sows, is essential for an economically successful pig production. Compared to their ancestor, the wild boar, domestic sows perform nest-building as part of maternal behaviour in a nearly unmodified way. However, the pre-parturient behaviour is considerably affected by the husbandry system and is only shown to its full extent when environmental circumstances allow it. If the sow cannot follow her natural behavioural need, for instance when no material is available, sheredirects her nest-building behaviour towards the pen or crate equipment. This results in stereotypes and stress, followed by a reduced reproduction performance. With regard to animal health and welfare, loose farrowing systems provide a good alternative while maintaining a high production performance. As long as these systems are not implemented, the farmers should provide at least suitable nest-building material like straw. Concluding, further research should evaluate and promote alternative enriched systems in order to support the economic use of these systems for the farmers.

Acknowledgement
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References


CHAPTER TWO

Characterisation of sows’ postures and posture changes with regard to crushing piglets

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Abstract
The aim of this study was to analyse different behavioural traits of sows to describe posture changes and to determine the influences of these traits on piglet losses. The behaviour of 386 German Landrace sows (with 438 pure-bred litters) was videotaped continuously starting 12 hours prepartum until 48 hours post partum in a nucleus herd for one year. From this population, 40 sows were randomly sampled with a block data design. Twenty sows which crushed one or more than one piglet (C-sows) were compared to 20 sows which crushed no piglets (NC-sows). The postural behavioural traits were analysed according to duration, manner and frequencies of positions (‘descending from standing to lying’ behaviour, ‘standing-up’ behaviour) as well as the time taken for various posture changes. Each respective trait was calculated according to the difference between NC-sows and C-sows.

Results revealed that prepartum, NC-sows were more restless; primiparous ones in particular performed more posture changes (P = 0.109) and tended to ‘stand up’ more often (P < 0.01). Additionally, they ‘stood’ more often (P < 0.05) and performed ‘nest-building’ behaviour with higher frequencies, particularly in the seventh (P < 0.01) and sixth hours (P < 0.1) before parturition and with longer durations than C-sows. Post partum, NC-sows performed no different activities in movement pattern compared to C-sows. However, compared to primiparous NC-sows, primiparous C-sows showed more ‘rolling’ movements (P < 0.01). C-sows preferred ‘ventral recumbency’ within ‘rolling’ movements (P < 0.05) and as the final position of ‘descending from standing to lying’ (P < 0.1). Furthermore, the bouts of ‘sitting’ behaviour of C-sows were much longer than of NC-sows, especially multiparous ones (P < 0.01). NC-sows performed ‘lateral recumbency’ much longer and also more often as the final position of ‘descending from standing to lying’ (P < 0.01). These results suggested that posture patterns of NC-sows and C-sows are different, especially ‘nest-building’ behaviour prepartum and ‘ventral-’ or ‘lateral recumbence’ post partum, indicating a possible use to characterise the maternal abilities of sows in minimising piglet crushing.

Keywords
Crushing; Posture changes; Farrowing; Maternal ability; Pig

1. Introduction
One major aim of pig production is the decrease in piglet losses to improve the economic success characterised by high numbers of weaned piglets per sow and year. The number of piglets weaned is determined mainly by piglet losses in the suckling period. In commercial
pig production, piglet mortality vary between 10 and 20% (Alonso-Spilsbury et al., 2007), presenting a considerable welfare and production problem. The majority of piglet deaths are observed in the first two days of lactation across several types of housing (English and Smith, 1975; Svendsen et al., 1986; Barnett et al., 2001; Hellbrügge et al., 2008a). Particularly with regard to loose-housed sows, a high number of crushed piglets are observed (Wechsler and Hegglin, 1997). Thus, the farrowing crate was introduced in the 1960s to decrease piglet mortality, especially the crushing of piglets by the sow, to make routine sow and piglet management easier for the stockperson, and to allow a greater number of animals to be kept per unit (Fraser and Broom, 1990; Edwards, 2002). However, 47.4% of suckling losses are related to crushing (Kunz and Ernst, 1987), especially within the first 24 hours post partum (Marchant et al., 2001).

In addition to the traditional traits of selection to improve litter size, such as piglets born alive or birth weight, the maternal ability of sows is becoming more and more important. Increased litter size puts higher demands on the ability of sows to raise large litters (Grandinson, 2005). Maternal ability, including maternal behaviour, can be described by different maternal traits (Wallenbeck et al., 2008). Large individual differences are seen in the behavioural patterns within sows, especially in posture changes (Marchant et al., 2000; Thodberg et al., 2002). Moreover, the frequency of posture changes and the quality of ‘descending from standing to lying’ movements have previously been used as indicators of maternal protectiveness (Wechsler and Hegglin, 1997). There are several different major body movements of sows which represent danger of crushing for the piglets (e.g. stand-lie, sit-lie, lie-sit) (Weary et al., 1996a). Wechsler and Hegglin (1997) described sows which are generally more careful than others when changing positions. Algers (1994) showed that sows performing better ‘nest-building’ and showing better responses to different stimuli by the piglets performed significantly better in a farrowing hut. Thus, pre-farrowing behaviour is very important for piglet survival (Heckt et al., 1988). Therefore, the understanding of sows’ behaviour is essential to support management possibilities in order to optimise the piglets’ chances of survival. Finally, improved maternal behaviour increases the welfare of piglets and sows (Grandinson, 2005).

The purpose of this study was to compare the behaviour of sows which did not crush any piglet with sows that crushed one or more than one piglet in order to identify the possible key features of sows’ behavioural patterns influencing the risk of crushing.
2. Material and methods

2.1. Animals and environment

Data were recorded in a nucleus herd of the German breeding company ‘Hülsenberger Zuchtschweine’ from January to December 2004. Data of 386 Landrace sows with 438 pure-bred litters were available. During lactation the sows were housed in conventional farrowing crates with dimension of 2.74 m x 1.75 m. The sows were fixed in diagonally ordered farrowing crates. No nesting material was provided to the sows. Twenty sows were crated per farrowing house, ordered by the calculated farrowing date. In the farrowing crate, underfloor heating and heat lamps were provided. The piglet nest area was located laterally in front of the sow’s head. Sows were managed in a one-week rhythm with a 21-day lactation period. The sows were fed once per day, and from the second day post partum twice per day. During the whole study time, no medication was administered.

2.2. Sampling methods

Videotapes were recorded using the HeiTel Player software program (HeiTel Digital Video GmbH, Kiel). Sixteen sows within one farrowing batch were filmed simultaneously by eight cameras. In this way, the movement patterns (frequency, duration, change of posture) of the sows were continuously observed from overhead with the period of 12 hours before parturition up to 48 hours after parturition. Overall, 26,280 hours of behaviour were recorded on videotapes. Subsequently, the duration (d; seconds) and the frequency (f; number per hour) of the behavioural traits were analysed by one person by using a self-written database to build data files for SAS (SAS, 2004).

2.3. Behavioural observations

The recorded single behavioural traits are given in Table 1.

Table 1: Recorded behavioural traits according to videotape analyses (modified by Lou and Hurnik, 1998)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Upright body position on extended legs with hooves only in contact with the floor</td>
</tr>
<tr>
<td>Sitting</td>
<td>Partly erected on stretched front legs with caudal end of body contacting the floor</td>
</tr>
</tbody>
</table>
Kneeling on front legs  Kneeling with both carpal joints on the floor  
Sternal recumbency  Lying on abdomen with front and hind legs folded under the body  
Ventral recumbency  Lying on abdomen with front legs folded under the body and visible hind legs  
Lateral recumbency  Lying on either side with all four legs visible  
Nest-building  Continuously oronasal contact with floor and head movements  
Rolling  All occurrences of postural changes between lying on one side to lying on the other side (side-swapping)  

‘Rolling’ movements were analysed in different positions from the end of the starting position to the beginning of the next position. The following ‘rolling’ movements were analysed: LL (lateral-lateral), VV (ventral-ventral), LV (lateral-ventral), VL (ventral-lateral). For example, the trait ‘lateral-lateral (LL)’ explained the duration of swapping from ‘lateral recumbent’ on the one side to ‘lateral recumbent’ on the other side. Additionally, the ‘rolling’ movements towards and away from the piglet nest were analysed.

‘Recumbency’ was defined as the sum of frequency of ‘sternal-‘, ‘ventral-‘ and ‘lateral recumbent’ positions. ‘Movement’ behaviour was defined as the sum of the frequency of ‘standing’, ‘sitting’, ‘kneeling on front legs’ and ‘recumbency’.

In the next step, the described behavioural traits were differentiated into 22 additional traits to analyse durations of different behavioural patterns with ‘standing-up’ or ‘descending from standing to lying’ in a special manner (Table 2).

Table 2: Differentiated behavioural traits for recorded behavioural patterns ([ascending behaviour indicated in italics, descending behaviour in normal font](#))  

<table>
<thead>
<tr>
<th>Behavioural trait</th>
<th>Following behavioural trait</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Sitting</td>
</tr>
<tr>
<td></td>
<td>Kneeling on front legs</td>
</tr>
<tr>
<td></td>
<td>Ventral recumbency (right side + left side)</td>
</tr>
<tr>
<td></td>
<td>Lateral recumbency (right side + left side)</td>
</tr>
<tr>
<td>Sitting</td>
<td><strong>Standing</strong></td>
</tr>
<tr>
<td></td>
<td>Kneeling on front legs</td>
</tr>
<tr>
<td></td>
<td>Ventral recumbency (right side + left side)</td>
</tr>
<tr>
<td></td>
<td>Lateral recumbency (right side + left side)</td>
</tr>
</tbody>
</table>
Kneeling on front legs

Standing

Sitting

Sternal recumbency

Ventral recumbency (right side + left side)

Lateral recumbency (right side + left side)

Sternal recumbency

Kneeling on front legs

Ventral recumbency (right side + left side)

Lateral recumbency (right side + left side)

Ventral recumbency (right side + left side)

Kneeling on front legs

Sternal recumbency

Lateral recumbency (right side + left side)

Lateral recumbency (right side + left side)

Kneeling on front legs

Sternal recumbency

Ventral recumbency (right side + left side)

For instance, the trait ‘standing-sitting’ explained the duration of postural change from ‘standing’ to ‘sitting’ posture.

2.4. Sample of animals and statistical analysis

Lehner (1992) proposed ‘sampling of all occurrences’ as the method of choice to generate accurate frequency and duration data. For our study, videotapes, each of 60 hours length, from 438 litters were available. To realise this examination, a block data design of 40 animals was chosen. Twenty sows without any crushed piglets (NC-sows) were randomly sampled by using uniform distribution procedure (SAS, 2004).

Table 3: Means, standard deviations (s.d.), minimum (min.), maximum (max.) and statistical differences (P-values) of the reproductive traits of NC-sows and C-sows (n = 40)

<table>
<thead>
<tr>
<th>Traits</th>
<th>Means±s.d.</th>
<th>min. -max.</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC</td>
<td>C</td>
<td>NC</td>
</tr>
<tr>
<td>Total number born per litter</td>
<td>9.8±2.67</td>
<td>11.25±2.57</td>
<td>4-15</td>
</tr>
<tr>
<td>Number born alive per litter</td>
<td>9.2±2.73</td>
<td>10.15±2.28</td>
<td>4-13</td>
</tr>
<tr>
<td>Number stillborn per litter</td>
<td>0.6±1.50</td>
<td>1.05±3.24</td>
<td>0-4</td>
</tr>
</tbody>
</table>
Sows with one or more crushed piglets within the first 48 hours after parturition (C-sows) were selected conforming the NC-sow group (Table 3), considering the matching criteria number of piglets born alive, parity and farrowing date (season). Significance of differences between the means of NC- and C-sows was tested by using the TTEST and NPAR1WAY procedure of SAS (2004).

Piglets’ deaths were defined visually on farm, and crushing was determined in combination with video analysis. Crushing was characterised as ‘no movement of trapped piglet after a change in the sow’s posture’, as described by Vieuille et al. (2003). The selected sows were healthy, which was determined by body temperature (max. 39.5° C) within three days after parturition and evaluation of the exterior correctness without extreme deviations determined by a linear scoring system before lactation, as described previously (Hellbrügge, 2007).

According to the matching criteria, a block data design was created arranging NC-sows and C-sows in pairs. The average parity number of pairs was 2.35 and ranged from 12 pairs as gilts and eight pairs from the third to the tenth parity. Five pairs had their farrowing date in March or April, ten pairs in May and June, and the rest in August and September.

Except for higher numbers of piglets born alive, C-sows did not differ in comparison to NC-sows. All litters were adjusted by cross-fostering post partum, depending on the litter sizes per farrowing group. The performance of sows and further data on the piglets was represented in detail by Hellbrügge et al. (2008a). The crushing mortality on the farm was 12.4%, with 8.8% within the first three days (Hellbrügge et al., 2008a).

In total, 20 C-sows were analysed which crushed 27 piglets within the first 48 hours post partum. Within the first 24 hours post partum, 70% of these piglets were crushed. Two-thirds of them were male with an average body weight of 1.28 kg. The observed crushing was performed in 63% by the hindquarter, in 32% by the shoulder and in 5% by the back. Most piglets were crushed while the sow performed ‘descending from standing to lying’ (63%), 22% were crushed during ‘rolling’ behaviour and only 15% piglets were crushed while the sow ‘stood up’.

Significance of differences between NC-sows and C-sows were analysed with a linear model using the MIXED procedure of the SAS statistical software package (SAS, 2004). The behavioural traits and the associated residuals were not normally distributed. For this reason, normally distributed residuals as a pre-condition of linear models could be realized by using differences. Differences in independent random variables will be approximately normally distributed (central limit theorem). Thus, for every behavioural trait, the difference between
the behavioural traits of C-sows was subtracted from the respective behavioural trait of NC-sows.

The model included the fixed effects of parity (‘first parity’ and ‘higher parities’), season for farrowing (‘March to April’, ‘May to June’ and ‘August to September’), and time interval to the beginning of farrowing, which was calculated in hours beginning with ‘12 h before farrowing’ and ending with ‘48 h after farrowing’. The time intervals before farrowing (prepartum) and beginning with farrowing (peri-/post partum) were analysed separately.

Model:

\[ y_{ijkl} = \mu + P_i + S_j + T_k + e_{ijkl} \]

with:

- \( y_{ijkl} \) = difference between NC-sow and C-sow (pair) of the respective traits
- \( \mu \) = overall mean
- \( P_i \) = fixed effect of the i-th parity class (i = 1, 2)
- \( S_j \) = fixed effect of the j-th season class (j = 1, 2, 3)
- \( T_k \) = fixed effect of the k-th time (k = -12, …, -1 hour and k = 0, …, 48 hour respectively)
- \( e_{ijkl} \) = residual effect

The differences are multiple measurements within sow pair over a period of time (12 h before or 48 h after farrowing). For such datasets it is assumed that the repeated measures are not independent and thus autocorrelated (Littell et al., 2006). Therefore, it was necessary to use applicable error covariance structures for valid statistical inferences. Different structures were compared for their ability to fit the model using the likelihood ratio test and criteria of Akaike (1973) and Schwarz (1978). Generally, measurements closer together have higher correlations than measurements with longer time gaps between them (Littell et al., 2006). Here, the first-order autoregressive model, AR(1), was chosen with Covariance Parameter Estimates between 0.85 and 0.20. The significance of fixed effects was tested by the F-test implemented in the MIXED procedure in SAS (SAS, 2004). With regard to the pre-conditions for linear models, homogeneity of variance was checked by plots of the standardised residuals against the predicted values. For instance, the plot of standardised residuals against the predicted values of the behaviour trait ‘standing frequency before farrowing’ showed the desired residual bond (Figure 1).
3. Results

3.1. Prepartum

The NC-sows ‘moved’ more often than the C-sows, except in the fifth and fourth hours before farrowing. Primiparous NC-sows in particular were more restless and performed on average 5.5 times more posture changes than C-sows (P > 0.05). Before farrowing, increased activity of NC-sows, especially primiparous ones, was confirmed by ‘standing’ behaviour. NC-sows ‘stood’ more often than C-sows (P < 0.05). Furthermore, increased activity of primiparous NC-sows in comparison with C-sows was confirmed by ‘nest-building’ behaviour. Key aspects of increased activity, characterised by the line of means, were observed in the seventh and fourth hours before farrowing (Figure 2).

Figure 1: Plot of standardised residuals against the predicted ‘standing’ frequency before farrowing
3.2. Post partum

From the beginning of parturition, ‘standing’ behaviour had significant differences in frequency and duration (LSM 94 seconds, P < 0.05) in primiparous NC-sows compared to primiparous C-sows. However, C-sows, especially multiparous ones, performed much longer bouts of ‘sitting’ (LSM 64 seconds) than multiparous NC-sows (P < 0.01). The means of ‘rolling’ frequency showed an increase after nearly one day, as indicated especially for C-sows, and equalised for all sows after this peak (Figure 3).
In comparison to C-sows, NC-sows showed tendencies for fewer and shorter ‘rolling’ movements. Particularly primiparous C-sows ‘rolled’ more often (P < 0.01), and needed 4 seconds longer than primiparous NC-sows to swap from one side to the other (P < 0.05).

Furthermore, there were significant differences in side-swapping: from ‘ventral recumbency’ to ‘ventral recumbency’ (VV), primiparous C-sows performed ‘rolling’ movements more often (P < 0.01) than primiparous NC-sows and with longer durations (P < 0.05). In contrast, multiparous NC-sows took a longer duration to swap sides from VV than multiparous C-sows (P < 0.05). From ‘lateral recumbency’ to ‘ventral recumbency’ (LV), primiparous C-sows showed ‘rolling’ movements more often than primiparous NC-sows (P < 0.05). Any other ‘rolling’ movements did not differ between NC-sows and C-sows. Additionally, tendencies of ‘rolling’ movements towards the piglet nest or away from the piglet nest could not be observed in NC-sows and C-sows.

Primiparous NC-sows showed a significant difference in the frequency of ‘standing-up’ behaviour in the form of ‘kneeling-sitting-standing’ compared to primiparous C-sows (P < 0.01). NC-sows were much more active.
Besides the differences in duration of ‘descending from standing to lying’, starting from ‘sitting’ position, primiparous C-sows took five seconds (LSM) longer than primiparous NC-sows. The primiparous C-sows ‘lay down’ more often than primiparous NC-sows (P < 0.1) with the final position of ‘ventral recumbency’. The primiparous NC-sows preferred the ‘lateral recumbency’ final position (P < 0.01).

C-sows performed a significantly longer duration of ‘ventral recumbency’ (LSM) than NC-sows several hours after parturition, especially within the first 15 hours post partum (Figure 4). The line of means describes an oppositional trend with shorter durations within the first 12 hours in ‘ventral recumbency’ (Figure 4).

In contrast, NC-sows showed significantly longer durations of ‘lateral recumbency’ at different times than C-sows. Furthermore, NC-sows performed longer and more often ‘descending from standing to lying’ with the ‘lateral recumbency’ final position than C-sows.

**4. Discussion**

Studies by Haskell and Hutson (1996) and Damm et al. (2003) showed that sows perform increased activity behaviour in terms of postural changes during the pre-farrowing period in different kinds of housing. In the present study, sows housed in crates, particularly
primiparous NC-sows, performed an activity expressed in increased ‘standing’ behaviour and decreased ‘descending from standing to lying’ prepartum. Jensen (1989) observed in loose-housed sows a peak of activity in the period 16 to 8 hours of pre-farrowing, especially ‘standing’, in which ‘nest-building’ behaviour typically occurred. At this time peak, the behaviour of crated NC-sows and C-sows differed significantly in the present study, as well. Especially primiparous NC-sows ‘stood’ more often than primiparous C-sows. Additionally, in this activity NC-sows performed significantly more often and in longer bouts ‘nest-building’ behaviour pattern equal to their wild ancestors, even in crates without any available ‘nest-building’ material. The onset and performance of ‘nest-building’ is both stimulated internally via hormones, for instance prolactin, and externally via feedback from the environment. With this environmental influence, the possibilities to perform ‘nest-building’ can be restricted to different extents in commercially farmed pigs, but elements of this innate behaviour are always shown (Wischner et al. 2009). Due to the lack of material, ‘nest-building’ behaviour was performed only against the floor and fittings of their crates. Damm et al. (2003) assessed that the crate environment restricted the sows either indirectly due to a feedback mechanism or directly by preventing physical activity, so that more fragmented ‘nest-building’ behaviour was observed in crates than in pens. However, in this study, sows in crates did perform ‘nest-building’ behaviour, and differences between NC-sows and C-sows were identified additionally. NC-sows performed longer ‘nest-building’ behaviour more often. In another study, non-crusher sows showed significantly more ‘nest-building’ activities before the onset of farrowing than crushers (Andersen et al., 2005). However, Pedersen et al. (2006) described that the passivity of sows, represented by low ‘nest-building’ activity, was followed by low post partum motivation for behavioural patterns and resulted therefore in safer postural changes for the piglets. Even though comparison between different studies is limited because of differences in the observed parameters and housing conditions, these results could not be confirmed in this study. Lower ‘nest-building’ activity as shown in C-sows, was followed by higher piglet mortality.

The reasons for crushing are difficult to analyse, since behaviour patterns which sows and piglets perform to avoid crushing need to be considered not only in their occurrence, but also in the way they are performed (Pedersen et al., 2006). In this respect, the motivation for ‘careful’ behaviour has to be regarded. In this study, further detailed observations to possible piglet responses associated with vocalisation from the dam could not be determined, because there was no audio information on the time-lapsed video records.
Another cause for crushing is related to litter size. Johnson et al. (2007) showed that crusher sows had more piglets born per litter than non-crusher sows. One biological reason for fatal trampling and crushing may be that it represents an alternative way of reducing maternal investment, especially in large litters (Andersen et al., 2005). In a similar way, the Parental Investment Theory (Evans, 1990) claims that any parental investment in the offspring lowers the parent’s ability to invest in future piglets, and is therefore decreased with higher parities (Held et al., 2006).

However, in larger litters, piglets’ body weights vary, and therefore, the risk of crushing is increased for the smaller ones. On the contrary, breeds with large litters, for instance Meishan sows, show lower losses due to crushing, because they are more vigilant and aware of the piglets’ location (Hohenshell et al., 1996).

Our results showed that C-sows preferred the ‘ventral recumbency’ for a longer duration and as final position of ‘descending from standing to lying’. This lying position does not allow the piglets’ full access to teats, as in ‘lateral recumbency’ (Damm et al., 2000). Therefore it has been reported that optimum maternal behaviour is characterised by passivity and ‘lateral lying’ (Jarvis et al., 1999; Hellbrügge et al., 2008b). Thodberg et al. (1999) found that after the initial, more active period, sows generally lie in ‘lateral recumbency’. Cronin and Smith (1992) observed a longer duration of lying in ‘lateral recumbency’ from 65% to 95% of total time the first day after farrowing. In our study, NC-sows performed in the first day after parturition significant longer bouts of ‘lateral recumbency’, which permitted the piglets to find and remain near the udder to consume colostrum.

The manner of ‘descending from standing to lying’ had an essential influence on the crushing risk in piglets (Vieuille et al., 2003). In the present study, only the final lying position after ‘descending from standing to lying’ differed between the NC-sows and C-sows. C-sows preferred more often ‘ventral recumbency’ after ‘sitting’ and ‘kneeling on front legs’, while NC-sows preferred ‘lateral recumbency’ after ‘sitting’ and ‘kneeling on front legs’. Consistent with Marchant et al. (2001), no association was detected between times taken to lie down and crushing. However, Damm et al. (2005) described the risk of crushing to be highest during fast and uncontrolled body descending, because piglets had less time to escape or to vocalize loudly. In agreement with this statement, in our study 70% of the piglets were crushed while the sow performed ‘descending from standing to lying’. The manners in which the sow ‘lay down’ were not relevant for the piglets’ deaths due to crushing by the sow.

Generally, the risk of crushed piglets rises when the piglets have consumed little or no colostrum, especially when the sow performs many postural changes (Weary et al., 1996b).
particular, ‘rolling’ behaviour was shown more often and in longer bouts by primiparous C-sows in comparison with primiparous NC-sows. In our study, 22% of all crushed piglets were related to ‘rolling’ behaviour. C-sows swapped sides from ‘lateral-’ or ‘ventral recumbency’ to ‘ventral recumbency’ more often than NC-sows. But in opposition to Damm et al. (2005), slower ‘rolling’ movements of primiparous C-sows were identified as risky behaviour. In the contrary, in multiparous NC-sows, slower ‘rolling’ movements decreased the risk for the piglets. This is incompatible with Svendsen et al. (1986), showing an increase of the crushing risk for sows in higher parities. This is most probably related to the gain in body size, resulting in a reduced agility and phlegmatic behaviour in general (Weary et al., 1998). The effects of the confinement by crates become more apparent in heavier multiparous sows that are slowed down in their ‘rolling’ movements. On the contrary, primiparous sows are still able to perform ‘rolling’ movements in a different manner and frequency due to their smaller size.

Usually, ‘sitting’ was an unavoidable stage during postural change from ‘lying’ to ‘standing’ whereas it was not necessary vice-versa from ‘standing’ to ‘lying’. C-sows performed a significant higher ‘sitting’ duration than NC-sows after parturition. After farrowing, sows in a ‘sitting’ posture could not stay close to their piglets. But this proximity is necessary to provide warmth and access to the udder to obtain adequate milk intake (Weary et al., 1996a). The most dangerous body movements for the piglets occurred when the sow ‘lay down’ in an uncontrolled manner, even from ‘sitting’ to ‘lying’ (Edwards et al., 1986). In the present study, only 11% of piglets were crushed by ‘descending from standing to lying’, starting with a ‘sitting’ position. By ‘descending from standing to lying’, 63% of the piglets were crushed. Despite this high percentage, no differences between NC-sows and C-sows in their ‘descending from standing to lying’ performance were observed. This might indicate the involvement of traits that were not assessed in our study, for instance a better responsiveness to their piglets or a different vocalisation in NC-sows.

5. Conclusion

A better understanding of behavioural patterns in farrowing behaviour is essential for increasing the proportion of piglets weaned and thus improving economic success in pig production. A significantly longer duration and higher frequency of standing posture, and a significant higher frequency in standing-up and lying-down combinations was performed by NC-sows in our study. This higher activity in NC-sows might express a better responsiveness towards their piglets. Further research with comprehensive sampling should concentrate on
traits with significant differences which have to be verified, indicating a possible use in selection of sows with optimal maternal abilities.

References


CHAPTER THREE

Pre-lying behaviour patterns in confined sows and their effects on crushing of piglets

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Abstract
In order to determine the influences of different posture patterns of sows on piglet losses, the present study aimed at the analysis of different elements of pre-lying behaviour peri and post partum. Over the course of one year, the behaviour of 386 German Landrace sows (with 438 pure-bred litters) in a nucleus herd was videotaped continuously starting 12 hours ante partum until 48 hours post partum. From these animals, 40 sows were randomly sampled with a block-data design. Twenty sows which crushed one or more than one piglet (designated as C-sows) were compared to 20 sows which crushed no piglets (designated as NC-sows). The analysis covered the frequency, duration and manner of the sows’ pre-lying behaviour. Combinations with other positions were assessed. The piglets’ resting-activity cycles and their location regarding the sow were also recorded. The respective behaviour was calculated according to the differences between NC-sows and C-sows. Results showed that post partum, NC-sows – in particular primiparous ones – performed ‘sniffing’ as an element of pre-lying behaviour significantly more often and with longer duration (30 seconds) than primiparous C-sows. Before ‘kneeling down on their front legs’ and changing into ‘lateral recumbency’, the primiparous NC-sows ‘sniffed’ more often than the C-sows (P < 0.01). Furthermore, NC-sows – especially multiparous ones – ‘looked around’ more often, also towards the piglet’s nest site, before descending from standing to lying by ‘kneeling on front legs’ (P < 0.05). ‘Nosing’, often in combination with ‘looking around’, was significantly more frequent in primiparous NC-sows than in primiparous C-sows. The duration of the sleeping and activity behaviour at the mammary gland had a tendency to be longer in the piglets of C-sows than in those of NC-sows (P < 0.1). Thus, these results indicate that elements of pre-lying behaviour of NC-sows and C-sows are performed in different ways. Therefore, ‘sniffing’, ‘looking around’, and ‘nosing’ as components of the pre-lying behaviour represent useful elements to characterise the maternal responsiveness of sows in relation to the crushing of piglets.

Keywords
Maternal behaviour; Nosing; Posture patterns; Responsiveness; Sniffing

1. Introduction
Good maternal behaviour is the most important pre-condition for high sow productivity. During domestication, most of the maternal behavioural patterns of sows remain unaltered (Špinka et al., 2000). However, in modern pig husbandry, increasingly larger litters demand a greater responsibility of the sows towards their offspring (Grandinson, 2005).
This responsibility is of enormous importance, in particular for neonatal piglets. Sows’ behavioural patterns, specifically postural ones, influence the piglets’ behaviour and result in consequences for milk intake and growth, but also in possible danger due to crushing. The danger of being crushed is high and prudent maternal responsiveness is urgently required especially within the first few days when the young piglets have a tendency to sleep directly next to the sow’s warm mammary glands and their co-ordination is not yet fully developed (Titterington and Fraser, 1975). The occurrence of crushed piglets is strongly related to individual differences in the protective behaviour of sows (Wechlsener and Hegglin, 1997; Andersen et al., 2005). The performance of maternal behaviour is strongly influenced by individual characteristics such as dominance, age, experience and the inter-individual variability based on genetic differences (Andersen et al., 2005). As shown by Hellbrügge (2007), the heritability of maternal behaviour during lactation was 0.14, offering a possibility to include these characteristics in selection programmes.

Responsiveness, attentiveness and protectiveness are substantial pre-requisites for adapting the sow’s behaviour to attain maximal maternal success. Pre-lying behaviour and the associated interaction between sow and piglet play an important role in minimising the risk of crushing (Marchant et al., 1996). In this way, early nose-to-nose contact within the first day post partum initiates the start of the bonding process between sow and piglet, enabling them to identify each other (Petersen et al., 1990). This allows the piglet to know which sow to approach for milk and protection; and the sow is assured that she is investing her resources in her own offspring (Horrell and Hodgson, 1992).

Due to high mortality rates by crushing within the most critical period of piglets’ survival during the first two days post partum, most sows today are housed in crates (Barnett et al., 2001; Johnson et al., 2007). The farrowing crate was designed to reduce piglet losses by restricting the body movements of the sow and to provide a zone of retreat for the piglets, especially the neonates (Baxter, 1984). Several studies have shown that behaviour during parturition is strongly affected by the environment (Pedersen et al., 2003; Jarvis et al., 2004). Therefore, the behaviour of confined sows may change due to the restriction of the housing environment (Fraser et al., 2001). However, Heckett et al. (1988) observed very similar postures and activities for maternal characteristics in different housing systems. Johnson et al. (2001) did not find any differences between sows in intensive indoor or outdoor production systems in the time spent by the piglets in direct contact with the sow.

This study analysed pre-lying and piglet-related behaviour in sows which did not crush any piglet and in sows that crushed one or more than one piglet, respectively. The objective of the
investigation was to compare pairs of sows with equal production parameters which only differed in the fact that they did or did not crush piglets.

2. Material and methods
2.1. Animals and environment

Data were recorded from January to December 2004 in a nucleus herd of the ‘Hülsenberger Zuchtschweine’ breeding company in Austria. Information of 386 Landrace sows with 438 pure-bred litters was available. Sows were housed in diagonally ordered farrowing pens of homogeneous type with dimension of 2.74 m x 1.75 m during lactation (Figure 1). Crate dimensions were individually adjusted to the size of each sow. No nesting material was provided for the sows. Twenty sows were penned per farrowing compartment, ordered by the calculated farrowing date. In the farrowing pen, underfloor heating and heat lamps were provided. The piglet nest area was located laterally beside the sow.

![Figure 1: Dimensions (m) and floor plan of the accommodation](image)

Key: H = heated area for piglets; F = food bowl; W = water; C = farrowing crate; CAM = position of the camera

The sows were managed in a one-week rhythm with a 21-day lactation period. They were fed once per day, and from the second day post partum twice per day. During the whole study time, no medication was administered.
2.2. Sampling methods

The HeiTel Player software program (HeiTel Digital Video GmbH, Kiel) was used to record videotapes. Eight cameras filmed sixteen sows within one farrowing batch simultaneously. The movement patterns (frequency, duration, transition of posture) of the sows were continuously observed from overhead within the period beginning with parturition (first piglet born) up to 48 hours after parturition. A total of 26,280 hours of video material were recorded. This data was analysed by one person with regard to the frequency (f; number per hour) and the duration (d; seconds or minutes) of the behavioural elements, and a self-written database to build data files for SAS (2005) was used.

2.3. Behavioural observations

The types of behaviour recorded are shown in Table 1. Furthermore, the resting-activity cycle of the piglets was analysed for duration and frequency. The start and end points for the time and location of the piglets’ sleeping and activity were recorded (Table 2). The start of sleeping and the end of activity were defined as the point at which at least 80% of the piglets were asleep (= rested in one body position). The end of sleeping and start of activity were characterised as the point at which at least 80% of the piglets performed movements (= moving, suckling, elimination).

Table 1: Recorded behaviour according to videotape analyses

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posture</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td>Upright body position on extended legs with hooves only in contact with the floor</td>
</tr>
<tr>
<td>Sitting</td>
<td>Partly erected on stretched front legs with caudal end of body contacting the floor</td>
</tr>
<tr>
<td>Kneeling on front legs</td>
<td>Kneeling with both carpal joints on the floor</td>
</tr>
<tr>
<td>Sternal recumbency</td>
<td>Lying on abdomen with front and hind legs folded under the body</td>
</tr>
<tr>
<td>Ventral recumbency</td>
<td>Lying on abdomen with front legs folded under the body and visible hind legs (right side, left side)</td>
</tr>
<tr>
<td>Lateral recumbency</td>
<td>Lying on either side with all four legs visible (right side, left side)</td>
</tr>
</tbody>
</table>
Sow’s lying position

Lying towards the piglet nest side  Ventral, lateral recumbency with the legs visible towards the nest

Lying averted from the piglet nest side Ventral, lateral recumbency with the legs visible turned away from the nest

Behaviour

Looking around Looking down and to the right and left sides

Looking to the piglet nest side Looking to the side towards the piglet nest only

Looking away from the piglet nest side Looking to the side opposite the piglet nest only

Nosing Snout contact of the sow with or close to the piglet's snout or body; snout contact of the piglet within one piglet length in front of the sow’s snout

Sniffing Sniffing the floor before descending from standing to lying

Table 2: Piglet locations

<table>
<thead>
<tr>
<th>Piglet location</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammary gland</td>
<td>At least 80% of the piglets resting at the mammary gland of the sow</td>
</tr>
<tr>
<td>Piglet nest</td>
<td>At least 80% of the piglets resting under the heat lamp of the piglet nest</td>
</tr>
<tr>
<td>Crate area</td>
<td>At least 80% of the piglets resting alone in the crate area</td>
</tr>
<tr>
<td>On the sow</td>
<td>At least 80% of the piglets resting directly on the sow (back, side, front, rear)</td>
</tr>
<tr>
<td>Between sow and piglet nest</td>
<td>At least 80% of the piglets resting huddled together between the sow and the piglet nest in the crate area</td>
</tr>
</tbody>
</table>

2.4. Statistical analysis

The ‘sampling of all occurrences’ was used (Lehner, 1992) to generate accurate frequency and duration of data. A block-data design was chosen to achieve data recording within a reasonable expenditure of time. Out of 438 litters, 20 sows without any crushed piglets (NC-
sows) were randomly sampled by using the uniform distribution procedure (SAS, 2005). For each NC-sow, one sow with one or more crushed piglets within the first 48 hours after parturition (C-sow) was selected, using the matching criteria of parity and farrowing date (season) (Table 3).

Table 3: Means ($\bar{x}$), standard deviations (S.D.), minimum (min.) and maximum (max.) of the reproductive traits of NC-sows and C-sows (n = 40)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Unit</th>
<th>NC</th>
<th>C</th>
<th>S.D.</th>
<th>NC</th>
<th>C</th>
<th>min.</th>
<th>max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number born per litter</td>
<td>Piglets</td>
<td>9.8</td>
<td>11.3</td>
<td>2.67</td>
<td>2.57</td>
<td>4</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Number born alive per litter</td>
<td>Piglets</td>
<td>9.2</td>
<td>10.2</td>
<td>2.73</td>
<td>2.28</td>
<td>4</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Number stillborn per litter</td>
<td>Piglets</td>
<td>0.6</td>
<td>1.1</td>
<td>1.50</td>
<td>3.24</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Number of crushed per litter</td>
<td>Piglets</td>
<td>0</td>
<td>1.4</td>
<td>0</td>
<td>0.67</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Piglets’ deaths were assessed visually on the farm by the scientist conducting the study, and crushing was determined in combination with video analysis. Crushing was characterised as ‘no movement of trapped piglet after a change in the sow’s posture’, as described by Vieuille et al. (2003). The selected sows were healthy, showing a body temperature of below 39.5°C within three days after parturition. Exterior traits were determined by a linear scoring system before lactation (Hellbrügge, 2007). Only sows without extreme deviations were considered. A block-data design was created arranging NC-sows and C-sows in pairs according to the matching criteria. The parity number of pairs ranged from twelve pairs as gilts and eight pairs from the third to the tenth parity with an average parity number of 2.35. Five pairs had their farrowing date in March or April, ten pairs in May and June, and the rest in August and September.

C-sows did not differ in comparison to NC-sows despite higher numbers of piglets born alive. All litters were adjusted by cross-fostering post partum depending on the litter sizes per farrowing group. The performance of sows and further data on the piglets were presented in detail by Hellbrügge et al. (2008). The crushing mortality on the farm was 12.4%, with 8.8% within the first three days (Hellbrügge et al., 2008). The total pre-weaning mortality value on the farm was 15.7%, and 10.0% in the litters of the 40 sows analysed in the study.

Twenty C-sows which crushed 27 piglets within the first 48 hours post partum were analysed. Seventy percent of these 27 piglets were crushed within the first 24 hours post partum. Two-
thirds of them were male with a mean body weight of 1.28 kg. The crushed piglets (n = 27) had a mean body weight of 1.25 kg, while the non-crushed piglets of C-sows (n = 176) weighed 1.54 kg and the piglets of NC-sows (n = 184) 1.63 kg. Crushing was performed in 63% of the incidents by the hindquarter, in 32% by the shoulder and in 5% by the back, mostly while the sow performed ‘lying-down’ behaviour (Wischner et al., 2009).

All piglets of NC-sows were defined as NC-piglets, while all piglets of C-sows were designated C-piglets. Their behavioural elements were analysed according to the sows’ data. A linear model using the MIXED procedure of the SAS statistical software package (SAS, 2005) was applied to analyse the significance of the differences between NC-sows and C-sows as well as between NC-piglets and C-piglets. The behavioural elements and the associated residuals were not normally distributed. Consequently, normally distributed residuals as a pre-condition of linear models were analysed by using differences calculated by the subtraction of the behavioural elements of C-sows (C-piglets) from the respective behavioural element of NC-sows (NC-piglets). Differences in independent random variables were approximately normally distributed (central limit theorem).

The fixed effects of parity (‘first parity’ and ‘higher parities’), season for farrowing (‘March to April’, ‘May to June’ and ‘August to September’) and time interval with ‘48 h after farrowing’ were included in the model (peri-/ post partum).

Model:

\[ Y_{ijkl} = \mu + P_i + S_j + T_k + e_{ijkl} \]

with:

- \( Y_{ijkl} \) = difference between NC-sows and C-sows (pairs) regarding respective behaviour
- \( \mu \) = overall mean
- \( P_i \) = fixed effect of the i-th parity class (i = 1, 2)
- \( S_j \) = fixed effect of the j-th season class (j = 1, 2, 3)
- \( T_k \) = fixed effect of the k-th time (k = 0, ..., 48 hour)
- \( e_{ijkl} \) = residual effect

The differences are multiple measurements within a sow pair over a period of time. It is supposed that the repeated measures are not independent and thus autocorrelated for such datasets (Littell et al., 2006). Therefore, it is necessary to use applicable error covariance structures for valid statistical inferences. For their ability to fit the model, different structures were compared (AR(1), TOEP(4), UN) using the likelihood ratio test and criteria of Akaike.
(1973) and Schwarz (1978). The first-order autoregressive model, AR(1), was chosen with Covariance Parameter Estimates between 0.67 and 0.09. The significance of the fixed effects was tested by the F-test implemented in the MIXED procedure in SAS (SAS, 2005). With respect to the pre-conditions for linear models, homogeneity of variance was checked by plots of the standardised residuals against the predicted values.

3. Results
The NC-sows, in particular primiparous ones, performed ‘sniffing’ as an element of pre-lying behaviour significantly more often (P < 0.01) and with a longer duration (P < 0.01) than primiparous C-sows. The means of ‘sniffing’ duration showed a decrease directly after parturition, followed by an increase at the 24th and 36th hour post partum. The ‘sniffing’ duration was extended in NC-sows especially after the first day (Figure 2).

![Figure 2: Differences (NC-C) in duration of 'sniffing' (LSM and S.E.) related to crushing and duration of 'sniffing' (mean) (n = 1,586)](image)

Within the fixed effect of parity, ‘sniffing’ before ‘kneeling on front legs’ followed by ‘lateral recumbency’ differed significantly (P < 0.05). Primiparous sows ‘sniffed’ more often than multiparous ones before descending from standing to lying. Especially primiparous NC-sows
‘sniffed’ more often (P < 0.01) in comparison to primiparous C-sows before ‘kneeling on front legs’ followed by ‘ventral recumbency’.

‘Looking around’ before descending from standing to lying and descending from standing to lying from ‘standing’ directly into ‘ventral or lateral recumbency’ without ‘kneeling on front legs’ did not differ between NC-sows and C-sows. ‘Looking around’ before ‘kneeling on front legs’ was significantly affected by parity (P < 0.05). Multiparous sows performed this behaviour more often than primiparous ones. Moreover, this behaviour was shown more frequently by NC-sows.

‘Nosing’ is a significantly more frequent behavioural pattern in NC-sows, especially in primiparous ones, than in C-sows (P < 0.01). Primiparous NC-sows ‘looked for nose-contact’ in average 3.8 times (LSM) more often than primiparous C-sows particularly in the time frame of one hour to twelve hours post partum. The means of ‘nosing’ frequency, especially in NC-sows, showed an increase after nearly half a day post partum (Figure 3).

The combination of the behavioural patterns ‘looking around’ and ‘nosing’ was performed more often by NC-sows than by C-sows. However, in combination with lying-down
behaviour or with ‘sitting’ or ‘standing’, no significant differences between NC-sows and C-sows were analysed.

The sow’s manner of descending from standing to lying towards or averted from the piglet nest did not influence or initiate the piglets’ willingness to fall asleep. The frequency and the beginning and end of the piglets’ sleep period in any location did not differ between NC-sows and C-sows. The duration of piglets’ sleeping behaviour varied at the mammary gland, but the difference was not significant: C-piglets tended to sleep on average 1.28 minutes (LSM) longer than NC-piglets in this position. The means were increased in C-piglets, with a decreased tendency after the 18th hour post partum (Figure 4), particularly for sleeping at the mammary gland.

Figure 4: Differences (NC-piglets – C-piglets) in duration of sleeping behaviour at mammary gland (LSM and S.E.) and duration of sleeping behaviour (mean) (n = 702)

The cycles of activity beginning and ending at the mammary gland were significantly different between NC-piglets and C-piglets. On average, C-piglets performed an 11-minutes (LSM) longer activity pattern than NC-piglets. Activity cycles starting and ending at the sow were longer in C-piglets as well. No differences between NC- and C-piglets were detected within the activity in the crate or between the sow and the piglet nest. Only in activity cycles
beginning and ending within the piglet nest did the NC-piglets – especially those of primiparous NC-sows – show longer duration than C-piglets, on average 8 minutes (LSM).

4. Discussion
As stated by Blackshaw and Hagelsø (1990), confined sows seem to be unable to turn and locate their piglets before lying down. However, the present study clearly shows that parts of inherent behavioural patterns are performed in confined environments as far as possible. In general, pre-lying behaviour such as rooting, pawing the ground, looking at and coming into contact with the piglets is shown more frequently within the first day after farrowing (Marchant et al., 2001; Damm et al., 2005; Pokorná et al., 2008). The major aim of these behavioural patterns is to attract the piglets’ attention before the sow lies down and to give them enough time to move (Marchant et al., 1996). In this way, this behaviour is directly related to piglet losses due to crushing. In the present study, NC-sows performed all evaluated pre-lying behaviour patterns significantly more often than C-sows, confirming the importance of this behaviour for the piglets’ survival.

The pre-lying behavioural pattern ‘sniffing’ is part of general lying-down behaviour. Harris and Gonyou (1998) reported ‘sniffing’ as common behaviour between sows and piglets in non-confined conditions. In the crated environment in the present study, sows nevertheless ‘sniffed’ on the floor and looked around first before lying down. This is especially relevant later on when piglets are resting in closer proximity. Particularly NC-sows performed ‘sniffing’ more frequently and with longer duration than C-sows, indicating the carefulness of NC-sows towards their environment. This is in accordance with Jensen (1986) and Marchant et al. (2001), who described ‘sniffing’ which led to contact with the piglets as maternal behaviour. In contrast to this, Blackshaw and Hagelsø (1990) did not find any association between the sow’s lying-down behaviour and behavioural patterns for checking the piglets’ location and for clearing the space.

‘Looking around’ is a further element of pre-lying behaviour (Marchant et al., 2001). In our study, multiparous NC-sows performed ‘looking around’ more frequently before descending from standing to lying than multiparous C-sows.

‘Nosing’ behaviour represents a social behaviour component, promoting the social bond between the sow and her piglets. ‘Nosing’ was described as an important maternal response of the sow, which affects the survival of the piglets (Ahlström et al., 2002), and is most frequently shown in the first five minutes after milk ejection (Whatson and Bertram, 1982). In contrast to Jensen (1988), who observed the first nasal contacts of free-ranging sows and their
piglets not before the end of the first week post partum, the primiparous NC-sows in particular had their first nose-contact within the first twelve hours after parturition in the present study. It also confirmed the results from Pedersen et al. (2003), showing that after the initial active period shortly after parturition, sows rest in lateral recumbency and do not respond to naso-nasal contacts by their piglets. Eventually, in a second phase, approximately 8 hours after birth, their maternal responsiveness to naso-nasal contacts increases. This is in accordance with another study (Blackshaw and Hagelsø, 1990), suggesting that the development of social behaviour is initiated by the sow on day one as well. The combination of the behaviour patterns ‘looking around’ and ‘nosing’ was shown more often by NC-sows than by C-sows. This emphasises the importance of these behavioural patterns for social bonding and as a precautionary measure before changing position, demanding higher responsiveness.

In the present study, no differences between the pre-lying behaviour of NC-sows and C-sows were analysed with regard to the piglets’ location. In contrast to this, Pokorná et al. (2008) reported more and longer pre-lying behaviour in sows when piglets were next to the sow or clustered in proximity. With regard to the piglets’ activity, a rise in position or more frequent changes in location before the sow descended from standing to lying were found neither in NC-piglets nor in C-piglets. In their activity cycles, however, C-piglets stayed significantly longer in the area with high crushing risk. Furthermore, activity cycles starting and ending in the piglet nest were significantly longer in NC-piglets than in C-piglets. This suggests that the NC-piglets huddled sooner in the piglet nest, putting themselves out of the risk zone. Even though there is the provision of a heated creep area as a preventative measure against crushing, reducing the time piglets spend next to the sow (Titterington and Fraser, 1975), piglets tend to lie next to the sow regardless of heat lamp location or air temperature (Hrupka et al., 1986). As shown by Hrupka et al., (1998), the heat lamp position and floor covering under the lamp does not normally affect piglets’ survival in the first three days post partum.

The ‘sleeping’ duration of C-piglets at the mammary gland was longer compared to the NC-piglets. Because C-sows preferred ‘ventral recumbency’ (Wischner et al., 2009), C-piglets had to stay next to the mammary gland in order to gain teat access. Consequently, the risk of crushing increased. How far these differences are related to an adequate milk intake was not determined in our study, but these questions are promising approaches for further examinations.
5. Conclusion

‘Sniffing’, ‘looking around’, and ‘nosing’ as essential parts of the pre-lying behaviour were performed in significantly different ways in sows that crushed and did not crush piglets. The study emphasises the existence of such differences and their inherent importance for the reduction of piglet losses, even in confined environments. Due to the economical relevance of the piglets’ survival and for animal welfare reasons, the assessment and evaluation of maternal behaviour is gaining increasing importance. Improved and simplified recording of maternal behavioural patterns might pave the way for studies on the genetic background of these properties, offering an alternative way to sustainably improve sow productivity within breeding programs.

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Characterisation of sows’ postures and posture changes with regard to crushing
CHAPTER FOUR

Analysis of sows’ posture patterns in relationship to different behavioural tests of sows

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Abstract
The aim of this study was to analyse different behavioural traits of sows in relationship to several behavioural tests carried out pre- and post partum to determine the interrelation to piglet losses. The behaviour of 386 German Landrace sows in a nucleus herd (with 438 pure-bred litters) was videotaped continuously for one year starting 12 hours prepartum until 48 hours post partum. From these animals, 40 sows were randomly sampled with a block data design. Twenty sows which crushed one or more than one piglet were compared to 20 sows which crushed no piglets. Postural behavioural traits were documented according to duration and frequencies of positions and analysed separately pre- and post partum (e.g. standing, sitting, lying-down). Sows’ reactions within three different behavioural tests were examined: separation of the sow from her litter after 24 hours post partum (SEPD1), after 21 days (SEPD21) and playback of a piglet’s distress call after 4 days (SCREAM). The sows’ maximum of reaction was assessed in an ordinal scale from score 1 (no reaction) to score 5 (very strong reaction). Spearman rank correlations were used to calculate the behavioural traits on the videotapes and the sows’ reactions in tests. In SEPD1, the sows’ responses were positively correlated to behavioural patterns (e.g. ‘nest-building’, ‘activity’), except the frequency of ‘rolling’ behaviour and duration of ‘resting’ behaviour. In SEPD21, the same tendencies of correlations were analysed as in SEPD1. In SCREAM, the sows’ responses were positively correlated to the frequency and duration in evaluated behavioural patterns, especially for ‘nest-building’ behaviour prepartum and pre-lying behaviour post partum. The results suggest that behavioural tests partly reflect sows’ maternal behavioural patterns which can be important criteria to analyse piglet losses.

Keywords
Maternal ability; Responsiveness; Piglet scream test; Separation tests; Posture changes

1. Introduction
Piglet mortality due to crushing is accompanied by substantial economic losses for the farmer (Grandinson et al., 2003). The selection of traits improving sow productivity has induced larger litters at birth and postulated improved maternal care. But these larger litter sizes go hand in hand with increased mortality rates (Roehe und Kalm, 2000). The most important factor for the piglet’s survival is the sow’s behaviour during the lactation period (Gäde et al., 2008). One indicator for maternal care is the responsiveness of the sow towards her offspring, but this maternal responsiveness towards the piglets and the activity of the sow vary after...
birth (Pedersen et al., 2003). Sows react more actively in the first two hours after birth, changing their postures more often, and being more reactive to piglets’ approaches. After the expulsion of the afterbirth, the responsiveness towards the piglets decreases, but increases again after 12 hours post partum (Pedersen et al., 2003). The initial passivity of sows is regarded as positive for the piglets, since they are allowed to suckle, while the risk of crushing is reduced (Jarvis et al., 1999).

Recording maternal behaviour using videotapes is time-consuming and not feasible in commercial stockbreeding situations. (Lensink et al., 2009). Thus, behavioural tests were developed, partly implemented into routine work, to record behavioural traits of sows with less time to be recorded under production conditions (Hellbrügge et al., 2008). The reaction of the sow towards human interactions characterised in different behavioural patterns is important for the survival of piglets, especially during the first days after farrowing. Stronger reactions by the sow towards the stockperson can be expressed by careless posture changes, increasing the piglets’ danger of being crushed (Lensink et al., 2009). Under production conditions, stockpersons have to gain access to the piglets within the first days after parturition (Chaloupková et al., 2008). At this time, the sow’s protectiveness is expressed by the sow’s reaction during the time her piglets are handled (Grandinson et al., 2003) and can be evaluated by the score of the separation test (Hellbrügge et al., 2008).

In the so-called piglet scream test, differences are measured between sows in their reactions to tactile and vocal stimuli from the possibly endangered piglets (Hutson et al., 1991; Wechsler and Hegglin, 1997). The slower the sow reacts and the longer the piglet is trapped beneath the sow, the higher the piglet’s risk of dying (Weary et al., 1996). The chance for survival increases when the sow reacts immediately. Vocal utterances of the piglets show a greater effect compared to tactile stimuli (Cronin and Cropley, 1991; Hutson et al., 1991). Moreover, Thodberg et al. (2002) observed that stronger reactions to piglets’ audio stimuli went along with the performance of less risky movement behaviour. The responsiveness of the sows to a sound of a screaming piglet has been used as an indicator of maternal behaviour (Grandinson et al., 2003; Hellbrügge et al., 2008).

In this study, reactions measured in behavioural tests and occurring posture patterns pre- and post partum were analysed. The aim of analysis was the evaluation of different behavioural tests in relationship to behavioural traits. In this way, the behavioural tests were examined as indirect traits implying the opportunity to improve the sows’ maternal features to reduce piglet mortality.
2. Material and methods

2.1. Animals and environment

Animals of this study were kept in a nucleus herd of the German breeding company ‘Hülsenberger Zuchtschweine’. In total, data and videotapes of 386 Landrace sows with 438 pure-bred litters were recorded in the time period between January and December 2004. The sows were managed in a one-week rhythm with a 21-day lactation period. During birth and lactation, sows were fixed in diagonally ordered farrowing crates of homogeneous type with dimensions of 2.74 m x 1.75 m during lactation. No nesting material was provided for the sows. Twenty sows were penned per farrowing batch, ordered by the calculated farrowing date. In the farrowing crate, underfloor heating and heat lamps were provided. The piglet nest area was located laterally in front of the sow’s head. From the first day the sows were fed once per day, and from the second day post partum twice per day.

2.2. Sampling of animals

A block data design of 40 animals out of this population was chosen to perform data analysis. Twenty sows without any crushed piglets were randomly sampled by using the uniform distribution procedure (SAS, 2005). Sows with one or more crushed piglets within the first 48 hours after parturition were selected conforming to the group of sows without any crushed piglets, considering the matching criteria number of piglets born alive, parity and farrowing date (season). The 40 sows selected were healthy, which was determined by body temperature (max. 39.5°C) within three days after parturition and evaluation of the exterior trait without extreme deviations determined by a linear scoring system before lactation, as described previously (Hellbrügge, 2007). All litters were adjusted by cross-fostering post partum, depending on the litter sizes per farrowing group (Table 1).

<table>
<thead>
<tr>
<th>Trait</th>
<th>$\bar{x}$</th>
<th>S.D.</th>
<th>min.</th>
<th>max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of piglets born per litter</td>
<td>10.5</td>
<td>2.7</td>
<td>4.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Number of piglets born alive per litter</td>
<td>9.7</td>
<td>2.5</td>
<td>5.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Number of stillborn piglets per litter</td>
<td>0.8</td>
<td>1.5</td>
<td>0.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>
2.3. Behavioural traits on videotapes

Video recording was accomplished by use of the HeiTel Player software program (HeiTel Digital Video GmbH, Kiel). Movement patterns (frequency, duration, transition of posture) of the sows were continuously observed from overhead within the period 12 hours before parturition up to 48 hours after parturition. Data was analysed by one person, considering the frequency (f; number per hour) and the duration (d; seconds, minutes or hours) of the behavioural traits since Lehner (1992) proposed ‘sampling of all occurrences’ as the method of choice to generate accurate frequency and duration data. Furthermore, a self-written database was used to create data files for SAS (SAS, 2005). The recorded single behavioural traits are given in Table 2.

Table 2: Recorded behavioural traits according to videotape analyses (modified by Lou and Hurnik, 1998)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Definition</th>
<th>Time of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing</td>
<td>Upright body position on extended legs with hooves only in contact with the floor</td>
<td>Pre-/ post partum</td>
</tr>
<tr>
<td>Sitting</td>
<td>Partly erected on stretched front legs with caudal end of body in contact with the floor</td>
<td>Pre-/ post partum</td>
</tr>
<tr>
<td>Kneeling on front</td>
<td>Kneeling with both carpal joints on the floor</td>
<td>Pre-/ post partum</td>
</tr>
<tr>
<td>legs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sternal recumbency</td>
<td>Lying on abdomen with front and hind legs folded under the body</td>
<td>Pre-/ post partum</td>
</tr>
<tr>
<td>Ventral recumbency</td>
<td>Lying on abdomen with front legs folded under the body and visible hind legs (right side, left side)</td>
<td>Pre-/ post partum</td>
</tr>
<tr>
<td>Lateral recumbency</td>
<td>Lying on either side with all four legs visible (right side, left side)</td>
<td>Pre-/ post partum</td>
</tr>
<tr>
<td>Nest-building</td>
<td>Continuously oronasal contact with floor and head movements</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Rolling</td>
<td>All occurrences of postural changes between lying on one side to lying on the other side (side-swapping)</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Sniffing</td>
<td>Sniffing the floor before descending from standing</td>
<td>Post partum</td>
</tr>
</tbody>
</table>
to lying

Nosing  Snout contact of the sow with or close to the piglet's snout or body; snout contact of the piglet within one piglet length in front of sow’s snout

Looking around  Looking down and to the right and left sides

Activity  Standing + sitting + kneeling in front of legs

Resting  Sternal- + ventral- + lateral recumbency

**2.4. Behavioural traits in tests**

Behavioural tests were performed as described in Hellbrügge et al. (2008). A separation test was performed within the period 24 hours after parturition (SEPD1) and before weaning after 21 day post partum (SEPD21). The sow’s reaction to the separation from her piglets was noted with emphasis on the strongest sow reaction shown during the test. Additionally, the sow’s initial position before the piglets were removed, and the sow’s final position were documented when the piglets were relocated.

Furthermore, a scream test (SCREAM) was made after the farrowing of all sows in one batch (in average four days post partum). Loudspeakers were placed in the central corridor for about two hours in order to customise the sows to the hi-fi system. When all sows were lying in lateral recumbency, the playback sound started with the scream test, a 30-second piglet distress call was played from a cassette and the sows’ reaction of posture changes was documented in an ordinal scale with five scores (Table 3).

<table>
<thead>
<tr>
<th>Score</th>
<th>Definition</th>
<th>SEPD1 (n = 40)</th>
<th>SEPD21 (n = 40)</th>
<th>SCREAM (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No reaction (e.g. sow remains in recumbent position)</td>
<td>20.0</td>
<td>10.0</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>Little reaction (e.g. sow raises head)</td>
<td>22.5</td>
<td>22.5</td>
<td>12.5</td>
</tr>
<tr>
<td>3</td>
<td>Medium reaction</td>
<td>22.5</td>
<td>37.5</td>
<td>57.5</td>
</tr>
</tbody>
</table>

Table 3: Definition and percentage (%) of the behavioural test score (modified by Hellbrügge et al., 2008)
(e.g. sow sits up)

4 Strong reaction 35.0 30.0 27.5
(e.g. sow stands up)

2.5. Statistical analysis

Data were analysed using SAS (SAS, 2005). Correlations between behavioural traits on the videotapes (Table 2) and scores of behavioural tests (Table 3) were analysed pre- and post partum. As a normal distribution could not be assumed for all data, Spearman rank correlations (r) were calculated between the behavioural traits on the videotapes and the sows’ reaction in the tests. Therefore observations of behavioural traits on the videotapes were averaged per time period (prepartum and post partum, Table 4). Results with an associate probability of less than or equal to 0.05 were considered as significant, while results with associated probability between 0.05 and 0.1 were considered as tendencies.

Table 4: Means (\( \bar{x} \)), standard deviations (S.D.), minimum (min.) and maximum (max.) of the traits on videotapes per observation period and behavioural tests (n = 40)

<table>
<thead>
<tr>
<th>Trait</th>
<th>( \bar{x} )</th>
<th>S.D.</th>
<th>min.</th>
<th>max.</th>
<th>Time of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest-building f  *</td>
<td>5.8</td>
<td>4.4</td>
<td>0.7</td>
<td>20.0</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Nest-building d **</td>
<td>196.3</td>
<td>154.6</td>
<td>19.0</td>
<td>499.8</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Rolling</td>
<td>0.9</td>
<td>1.2</td>
<td>0.0</td>
<td>4.2</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Activity f  *</td>
<td>19.6</td>
<td>8.6</td>
<td>5.2</td>
<td>42.8</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Activity d **</td>
<td>1031.0</td>
<td>496.2</td>
<td>253.2</td>
<td>2136.0</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Resting f  *</td>
<td>9.9</td>
<td>4.8</td>
<td>2.9</td>
<td>25.8</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Resting d **</td>
<td>2462.0</td>
<td>508.1</td>
<td>1461.0</td>
<td>3346.0</td>
<td>Prepartum</td>
</tr>
<tr>
<td>Sniffing f  *</td>
<td>0.8</td>
<td>0.7</td>
<td>0.0</td>
<td>3.4</td>
<td>Post partum</td>
</tr>
<tr>
<td>Sniffing d **</td>
<td>31.6</td>
<td>28.5</td>
<td>0.0</td>
<td>133.7</td>
<td>Post partum</td>
</tr>
<tr>
<td>Nosing f  *</td>
<td>8.2</td>
<td>3.8</td>
<td>2.0</td>
<td>23.6</td>
<td>Post partum</td>
</tr>
<tr>
<td>Looking around f *</td>
<td>0.9</td>
<td>0.5</td>
<td>0.1</td>
<td>2.1</td>
<td>Post partum</td>
</tr>
<tr>
<td>Activity f  *</td>
<td>3.8</td>
<td>1.4</td>
<td>1.5</td>
<td>6.9</td>
<td>Post partum</td>
</tr>
<tr>
<td>Activity d **</td>
<td>259.9</td>
<td>99.7</td>
<td>78.4</td>
<td>475.0</td>
<td>Post partum</td>
</tr>
<tr>
<td>Resting f  *</td>
<td>2.3</td>
<td>1.1</td>
<td>0.8</td>
<td>4.8</td>
<td>Post partum</td>
</tr>
<tr>
<td>Resting d **</td>
<td>3320.0</td>
<td>100.0</td>
<td>3104.0</td>
<td>3515.0</td>
<td>Post partum</td>
</tr>
</tbody>
</table>
3. Results

Positive correlations were found between SEPD1 and ‘nest-building’ behaviour (Figure 1). More reactive sows in tests performed more frequent \( r = 0.28 \) and longer \( r = 0.24 \) ‘nest-building’ behaviour as well as longer bouts of ‘activity’ behaviour \( r = 0.29 \). Duration in ‘resting’ behavioural patterns \( r = -0.12 \) was negatively correlated towards the sows’ reactions in SEPD1. All correlations were considered insignificant. Similar results were found in SEPD21.

![Graph showing correlations between different behavioural traits and sows' reactions in SEPD1 and SEPD21](image)

Figure 1: Correlations between different behavioural traits prepartum and sows’ reactions in SEPD1/ SEPD21 \( n = 40 \)
After parturition, behavioural traits were similarly correlated in SEPD1 as prepartum (Figure 2). ‘Activity’ was positively correlated and the duration of ‘resting’ was negatively correlated in SEPD1. The only significant rank correlation was calculated between the frequency of ‘sniffing’ and the sows’ reactions in SEPD1 (P < 0.05, Figure 2).
Figure 3: Correlations between different behavioural traits pre- and post partum and sows’ reactions in SCREAM (n = 40)

Sows with higher scores in SCREAM had a tendency to perform longer (r = 0.30) and more frequent (r = 0.34; P < 0.05) ‘nest-building’ behaviour prepartum (Figure 3). ‘Rolling’ behaviour (r = 0.19) as well as longer bouts of ‘activity’ behaviour (r = 0.29) were positively correlated with more reactive sows. Only the ‘resting’ behaviour in general was negatively correlated (r = -0.05; r = -0.26) towards sows with more reaction in SCREAM.

Post partum, more reactive sows in SCREAM performed tendentially higher frequencies and longer durations in all calculated behavioural traits except the duration of ‘resting’ behaviour (r = -0.36) and ‘nosing’ behaviour (Figure 3). Significant rank correlations were only calculated for ‘sniffing’ (P < 0.05) and ‘looking around’ behaviour (P < 0.01) with more reactive sows in SCREAM post partum.

4. Discussion

In this study, behavioural tests indicating a sow’s maternal ability were tested in relation to different behavioural traits. Frequencies and durations of ‘nest-building’ behaviour prepartum
were positively correlated with sows, which had a higher test score in SEPD1, indicating a
stronger protective reaction by the sow towards her piglets within the first day post partum.
‘Nest-building’ behaviour is an important part of innate maternal behavioural patterns
prepartum (Wischner et al., 2009). Sows showing distinctive ‘nest-building’ behaviour and a
high response to separation can be regarded as responsive mothers. Positive correlations
between test scores and the duration of ‘activity’ behaviour hint to more reactive sows
prepartum. These results were consistent with the assessed negative correlations between
sows’ reactions in SEPD1 and ‘resting’ behaviour.
Post partum, sows showing higher test scores in SEPD1 were more active in most behavioural
traits. The basis for a strong reaction in SEPD1 is a well developed bond between sow and
piglets. This bond is established by ‘sniffing’ as part of the pre-lying behaviour, also coming
into contact with the piglets before the sow descends (Marchant et al., 2001).
When evaluating the use of SEPD1, two points have to be considered: on the one hand, a
highly responsive sow is preferred, but on the other hand, calmer sows with less frequent
posture changes, passivity and lateral lying allow their piglets full access to the teats (Damm
et al., 2000). Furthermore, test results can be influenced by a possible weakness of the sow
shortly after parturition, followed by slow reactive behaviour (Hellbrügge et al., 2008).
In SEPD21, the correlation of ‘resting’ and ‘nosing’ behaviour and reaction of the sows was
positive related. This emphasises the importance of ‘resting’ behaviour, essential for the
piglets’ milk supply (Jarvis et al., 1999). ‘Nosing’ as part of suckling behaviour intensifies the
contact between the sow and her piglets described by Whatson and Bertram (1982) and
simultaneously improves the survival of the piglets (Ahlström et al., 2002). In SEPD21,
correlations were weaker and more heterogenous compared to correlations in SEPD1 pre- and
post partum. This might be due to the time interval between the behavioural observations and
the test, which took place three weeks later. This means that the behavioural test SEPD21 is
not feasible to describe maternal behaviour defined by behavioural traits.
In SCREAM, sows showing stronger reactions performed ‘nest-building’ prepartum more
often and for longer periods. Different and complex stimuli have effects on the performance
of ‘nest-building’ behaviour. In SCREAM, only the acoustic component was tested, while
stimuli of a tactile nature were neglected. However, behavioural reactions towards an acoustic
stimulus indicate well developed mothering abilities. Sows with higher reactions in SCREAM
performed ‘rolling’ movements more often pre- and post partum. Their more frequent
‘rolling’ movements might imply their high response to the piglet scream. A fast reaction to
the scream can prevent piglets, possibly trapped after ‘rolling’, from being crushed (Thodberg
et al., 2002; Vieuille et al., 2003). Prepartum, the frequency and duration of ‘activity’
behaviour was positively correlated in SCREAM. Sows which performed more posture
changes prepartum were more responsive to a piglet distress call after farrowing.
Furthermore, ‘sniffing’ was analysed more often and for longer periods post partum in sows
with high scores in SCREAM, suggesting a conformance between the tactile and acoustic
nature of these active and reactive behavioural patterns. The frequency of ‘looking around’
behaviour was positively correlated in SCREAM. ‘Looking around’, also performed as ‘pre-
lying’ behaviour, expresses the sow’s attentiveness towards the environment and her piglets
(Marchant et al., 2001). The reaction to SCREAM is also based on this attentiveness.

5. Conclusion
Posture patterns and behavioural tests are indicators of maternal ability in sows. Individual
variations in posture patterns contribute crucially to the reproductive success of the sow. The
use of behavioural tests alone to define sows with good maternal behaviour is difficult.
Further research should concentrate on more suitable behavioural traits to evaluate maternal
ability in sows in test situations.

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GENERAL DISCUSSION

The pre-weaning death of piglets is a problem with economic and animal welfare consequences in modern pig production (English and Morrison, 1984). Crushing by sows has commonly been reported as the major cause of losses in born-alive piglets (Svendsen et al., 1986). The definition of crushing, and thus inter-study comparability, is difficult. On the one hand, the on-farm diagnosis of crushing piglets is hard to perform, because missing observation often ends in misdiagnosis (Edwards, 2002). On the other hand, the correct interpretation of data within the chronological context is difficult. For instance, starvation, caused by reduced or inadequate food intake can serve as the primary cause for piglet death. Malnourished piglets tend to spend more time next to the sow (Weary et al., 1996), and are, furthermore, too weak and slow to react quickly enough to the body movements of the sow. Often this starvation itself is only a secondary reason for piglet death. Starvation is caused by several unfavourable circumstances, such as perinatal hypothermia in the piglets (Edwards, 2002) or post partum dysgalactia syndrome in the sow (Gerjets and Kemper, 2009), resulting in an insufficient colostrum intake. Such immune-reduced piglets are more likely to be crushed than healthy piglets (Fraser, 1990).

In this thesis, sows that definitely caused the death of at least one piglet by crushing were defined as crusher-sows (C-sows). These C-sows were compared to non-crusher-sows (NC-sows) which did not crush any piglet. As in practice, the reasons for and the manner of crushing were not further analysed. Only sows which crushed one or more piglets within the first 48 hours after birth were chosen, because in this time frame, the risk of crushing is highest (Svendsen et al., 1986).

To reduce piglet mortality and especially losses due to crushing, farrowing crates were developed (Edwards and Fraser, 1997). They were designed to restrict wide-ranging body movements of the sow and to create a safe area for the piglets outside the crate beyond the sow’s reach. Due to the confinement by the crate, sows were subsequently restricted in their pre-parturient behaviour. They were prevented from choosing a nest-site and could not perform ‘nest-building’ behaviour, as it is typical for pigs (Jensen 1989). However, research on alternative farrowing systems allowing more space for the sows showed an increased crushing risk for piglets. Nevertheless, the growing public concern about intensive livestock production has led to major doubts on farrowing crates. The effectiveness of farrowing crates in reducing piglets mortality caused by crushing is being discussed more and more
controversially, and the actual influence of the individual sow’s maternal ability is becoming increasingly important.

**Maternal behaviour**

Information on the genetic variation of maternal ability in sows is rare and available heritabilities are generally low (Henne, 1996; Grandinson et al. 2003; Gäde et al., 2008; Hellbrügge et al. 2008). Furthermore, the trait ‘maternal ability’ is complex, combining several aspects of maternal behaviour (Figure 1).

![Figure 1: Traits that are used to measure maternal ability of sows. Traits regarded in this study are marked grey.](image)

Most aspects of the maternal behaviour of sows have not changed significantly by domestication (Špinka et al., 2000). Though, variability in maternal behaviour exists between sows, and especially the frequency of posture changes and the quality of lying-down movements have been used previously as indicators for maternal protectiveness (Wechsler and Hegglin, 1997). Špinka et al. (2000) demonstrated that the traits of locomotion manner, protectiveness and nursing activity in domestic and feral pigs are not related to each other and
therefore should be considered separately. This indicates that maternal behaviour cannot be described sufficiently by ‘emotionality’ or ‘temperament’ in the narrow sense, but is a complex trait with more than one dimension.

Prepartum – ‘Nest-building’ behaviour

‘Nest-building’ behaviour in *Suidae* (pig) represents unique maternal behaviour which cannot be noticed in other ungulates or mammals in general. It is an important part of the reproductive behaviour of sows, taking place in the periparturient period. It is performed without any differences between breeds of different local origin, as shown by the comparison of ‘nest-building’ behaviour in very fertile Chinese breeds and European breeds (Meunier-Salaün et al., 1991).

If appropriate space and material are available, sows build a farrowing nest that provides shelter for their piglets, particular with respect to thermoregulation. The sows’ will to build a nest is not prevented by confinement. The behavioural pattern was divided into a preparing internally regulated phase, characterised by the digging a shallow hole, and into a subsequent material-oriented phase with the actual ‘nest-building’, which depends more on the feedback from the nest-site and on external stimuli (Jensen, 1993). The decreased performance of the material-oriented behaviour in crated sows, and additionally, a strong tendency for longer ‘nest-building’ phases may be caused by reduced possibilities to achieve feedback from the nest-site (Damm et al., 2003). This lack of satisfactory feedback could be stressful and result in higher heart rates before farrowing (Jensen and Toates, 1993). If bedding is provided, the comfortable lying area can serve as feedback stimuli, giving ‘udder comfort’ to the sows (Baxter, 1983).

‘Nest-building’ behaviour of pigs is based on fixed action patterns, and is already performed in its basic elements by six-day old piglets (Gundlach, 1968). ‘Rooting’, ‘pawing’, ‘mouthing’, ‘gathering’, and increased restlessness associated with ‘nest-building’ behaviour occurs most distinctly 12 hours before farrowing (Algers and Uvnäs-Moberg, 2007). The intensity of ‘nest-building’ behaviour depends on the environmental surroundings. Moreover, age, parity or previous housing experiences could affect ‘nest-building’ (Thodberg et al., 1999). In free-ranging sows, nest material is gathered dependent on the habitat, the season and its properties to stake, stuff or protect (Arey et al., 1991). Ickes et al. (2005) reported a profound impact of the ‘nest-building’ of wild sows on the scrub vegetation in primary lowland rain forests in Malaysia and Sumatra. However, farrowing crates and slatted floors without nest material hinder much of the ‘nest-building’ behaviour, even though many of the
behavioural elements are still present. Crated sows showed ‘nesting-like’ behaviour, for instance the unsuccessful gathering of nesting material with the mouth, resulting in rooting and mouthing of the pipes and waterers, since only these items were available for oral manipulation (Hartsock and Barczewski, 1997). The animals grind their teeth, bite and root at the rails. Such activities can lead to injuries and apparent exhaustion (Hansen and Curtis, 1980). Farrowing in crates tends to be more stressful than in pens with nest material, even if adaption to crate environments occurred (Jarvis et al., 2001). With the implementation of the EU Directive 2001/88/EC, this stress might be increased, since all sows have to be loose-housed during the majority of the gestation period, but are moved to the restricted environment of farrowing crates before parturition (Boyle et al., 2000). The consequences of stress in the peripartum period are various: Besides the restraint-stillbirth hypothesis (Baxter and Petherick, 1980), an increased risk of crushing of newborn piglets during parturition has been documented (Thodberg et al., 1999). Moreover, stress results in slower parturition times (Cronin et al., 1994), and a decreased duration of suckling time and an increased number of suckling sessions terminated by the sow (Herskin et al., 1999). Lower responsiveness to piglet distress calls have been reported as well (Thodberg et al., 2002). Nest material is usually not offered, resulting in a more passive behaviour prior to farrowing and increased activity at the beginning of farrowing (Cronin et al., 1993). With more space and the provision of adequate nest-building material, maternal behaviour and sows’ welfare have improved, leading to higher survival and growth rates in piglets (Damm et al., 2003). On the contrary, alternative spacious housing systems result in similar piglet mortality rates as observed in conventional systems (Weber et al., 2007). However, enriched environments and the selection of sows showing a genetic determination for positive maternal behaviour might offer an opportunity to reduce these losses (Johnson et al., 2007).

‘Locomotion’ behaviour

In the present study, increased activity behaviour in terms of postural changes was performed especially in primiparous NC-sows. Recent studies have reported a peak of ‘activity’ in the period about 12 hours before farrowing (Jensen, 1989). Especially ‘standing’, accompanied by more frequent and longer periods of ‘nest-building’ behaviour, was performed by NC-sows. Due to the restricted feedback mechanisms in crates (Damm et al., 2003), only fragmented ‘nest-building’ behaviour was observed. Although no nest material was available, differences between NC-sows and C-sows were recognised: NC-sows performed ‘nest-building’ behaviour longer and more frequently. The observation of Heckt et al. (1988) that
pre-farrowing behaviour is important for piglets’ survival was confirmed. In contrast to this, Pedersen et al. (2006) described that the passivity of sows, represented by low ‘nest-building’ activity, was followed by low post partum motivation for behavioural patterns and resulted therefore in safer postural changes for the piglets. Lower ‘nest-building’ activity, as shown by C-sows, was followed by higher piglet mortality. Higher activity patterns before birth, longer ‘lateral recumbency’ and calmness after birth, which improved the supply of milk for the piglets, were reported for the NC-sows. On the contrary, Weary et al. (1996) did not find any relationship between behaviour patterns and piglets’ mortality. Many different environmental and genetic factors influence the behaviour (Figure 2).

Figure 2: Factors influencing sows’ behaviour

The performance of posture patterns such as descending and ascending movements in a controlled manner depend on body control. This can only be conducted by sows on comfortable flooring without physical impairments such as poor leg constitution, inappropriate body size or a lack of muscular strength.

Diseases, especially post partum dysgalactia, bad leg constitution or obesity make sows’ movements highly dangerous for the piglets, since the sow is less careful or her ability to control the movement changes is reduced (Damm et al., 2005). Pain could be followed by carelessness towards the piglets and a higher risk of crushing. At higher parities, the sows gain body weight, leg problems increase, and litters become more irregular with respect to the
piglets’ growth (Weary et al., 1998), resulting in an increased risk of crushing. Diseases can also cause a lack of milk, weakening the piglets and resulting in a higher exposure to crushing. In our study, the standardisation of conditions led to the exclusion of diseased sows. Only healthy sows with non-febrile body temperature (max. 39.5° C) and fundamental correctness, proven by a linear scoring system, were included in the study. In this way, it was possible to evaluate behaviour movement patterns without any effects on health. Additionally, a sufficient food supply, matched to individual demands, is essential for sows’ health. Decubital ulcers and abrasions in thin sows could restrict or change movement patterns. Medical treatments, such as the administration of hormones, were not assessed in our study, but can influence maternal behaviour (Widowski and Curtis, 1989; Castrén et al., 1993). In most intensive sow productions, sows change from their loose-housed group to individual crates one week before farrowing. Especially for primiparous sows, this might go along with stress because of the new environment and the physical separation. In multiparous sows, already accustomed to the crates, stress might be caused by the association of the crated situation with parturition and natal pain. A reduction of stress, resulting in higher embryo survival (Baxter and Petherick, 1980) can be achieved by enriched environments. Stress and its consequences during parturition, including the ‘nest-building’ activity prepartum, is often shown by higher activity expressed by increased restlessness and significant larger number of postural changes (Marchant and Broom, 1993; Jarvis et al., 2001). Therefore, the evaluation of posture changes and activity patterns can be used to assess sow welfare in husbandry systems. Furthermore, and even more important, these behaviour analyses offer a way to evaluate the maternal ability of the sows.

**Post partum – ‘Pre-lying’ behaviour**

Parts of inherent behavioural patterns are performed in altered, confined environments as far as possible. This was shown for ‘pre-lying’ behaviour in crated sows such as ‘rooting’, ‘pawing the ground’, ‘looking at’ and ‘coming into contact’ with the piglets, especially in the first day after farrowing (Marchant et al., 2001; Damm et al., 2005; Pokorná et al., 2008). In contrast to this, Blackshaw and Hagelsø (1990) stated that confined sows were unable to turn and locate their piglets before ‘lying-down’. In this study, NC-sows performed ‘pre-lying’ behavioural patterns significantly more often than C-sows. The major aim of these behavioural patterns is to attract the piglets’ attention before the sow changes from ‘standing’ to ‘lying’, giving them enough time to move.
The behaviour ‘sniffing’ in combination with ‘looking around’ was performed before ‘lying-down’ in order to check the piglets’ location and to clear the space. This indicated a kind of carefulness of NC-sows towards the piglets and their environment.

Naso-nasal contact between the sow and the piglet is mostly shown as part of the suckling behaviour, initiating milk-ejection (Whatson and Bertram, 1982). The complex behavioural features of nursing behaviour as described by Algers (1993) or neo-nursing and cyclic-nursing (Lewis and Hurnik, 1985) could not exactly be determined in the videotapes. Therefore, nursing as a component of maternal behaviour was not considered, neither were the four phases of nursing order development (Hartsock and Graves, 1976) and sucking behaviour phases (Fraser, 1980). ‘Nosing’ behaviour was regarded as a ‘social’ behaviour component, promoting the social-bonding between sow and piglet. ‘Nosing’ was assessed as an important maternal response of the sow, which affects the survival of the piglets (Ahlström et al., 2002).

With the development of the mother-young relationship, maternal care was possibly improved, to be more responsive to piglet stimuli e.g in a trapped situation. This reactive behaviour of the sows was often determined as the basis and the origin for their interaction with the piglets. Blackshaw and Hagelsø (1990) claimed that the behaviour of the sow towards her piglets was totally reliant on the piglets’ behaviour towards the sow and therefore only reactive. This could not be confirmed by our study. The combination of the behaviour patterns ‘looking around’ and ‘nosing’ clearly showed the importance of these movements for social-bonding and as a precautionary measure before changing position, resulting in a higher responsiveness before ‘lying-down’.

Concerning the piglets’ activity, the first three days in the piglets’ life are spent in direct proximity to the sow, whether ‘active’ behaviour or ‘resting’ behaviour (Blackshaw and Hagelsø, 1990). During this time, ‘pre-lying’ behaviour is essential for the survival of the piglets. In our study, increased ‘activity’ or more frequent changes of location before the sow’s descent could be found neither in NC-piglets nor in C-piglets. These results suggest that not only the mechanical performance of posture patterns, but also the individual carefulness of the sow is important. Piglets generally look for the satisfaction of all their olfactory, acoustic and tactile needs (Hrupka et al., 2000). This is usually provided by the sow, and therefore, they try to keep in proximity (Welch and Baxter, 1986). With heated creep areas, the time piglets spent next to the sow should be reduced. Hrupka et al. (1998) proclaimed that this only works after the third day post partum. Because of different optimal temperatures for piglets and sows, the heated area should not be too close to the sow’s crate.

The dams are negatively affected by high temperatures (Algers and Jensen, 1990), possibly
followed by reduced milk production and decreased motions endangering the piglets. Because of the lower milk intake, the piglets stay next to the udder, additionally increasing the crushing risk. Definite temperature gradients in the environment support the sow’s health and welfare and help piglets to find their way to the udder and back to the heated creep area. Generally, good maternal behaviour, characterised by the performance of ‘pre-lying’ behaviour, is based on the intensive social-bonding between mother and offspring and offers responsiveness, attentiveness, and protectiveness towards the offspring, and results in higher survival rates (Grandinson, 2005).

**Behavioural tests**

One way to evaluate sows’ maternal behaviour are behavioural tests. In this study, the separation test after birth (SEPD1), the separation test at 21st day (SEPD21) and the piglet scream test (SCREAM) were used. The sows’ maximum of reaction was assessed and classified into different test scores (score 1 to score 5), which were analysed in relationship to different posture patterns pre- and post partum. Different correlations of behavioural test and respective behavioural traits pre-and post partum were observed. Slight tendencies were recognisable, but the low numbers of animals have to be considered, resulting in controversial and/or low correlations of behavioural traits and behavioural tests. For all tests, the restriction by the crate was not regarded. Additional difficulties can be attributed to the insufficient congruence of the behavioural tests and the assessed locomotion pattern: in posture patterns, the pure action is described, while in the tests, the role of additional factors such as responsiveness, carefulness and protectiveness should not be underestimated. Regarding the practical use of the test, especially in SEPD1, its restriction should be kept in mind: results could be falsified due to the possible weakness of sows shortly after birth and the following low expression of reactive behaviour (Hellbrügge et al., 2008). Better results are expected in SEPD21 because piglet losses are reduced in more reactive sows in SEPD21 (Hellbrügge et al., 2008). In our study, sows showing distinctive ‘nest-building’ behaviour and a high response towards separation can be regarded as responsive mothers. However, correlations between SEPD21 and different behavioural traits were tendentially less distinctive than between SEPD1 and different behavioural traits. This might be dependent on the time interval between the performance of the behavioural tests and the behavioural observations. In SCREAM the comparison with posture patterns is probably complicated by the different nature of the stimuli. For instance, the comparison of ‘nest-building’, as active behaviour mainly influenced by internal influences and external stimuli of tactile nature.
(Jensen, 1993), and SCREAM, demanding a reactive behaviour regarding acoustic signals (Hutson et al., 1991), is difficult. However, with regard to the positive correlations in the behavioural traits, SCREAM seemed to give the most suitable hints to the mothering ability.

Another problem in the rating of behavioural test scores is the comparability with other behavioural tests in literature, since the tests are not standardised. Different traits with varying definitions to characterise the maternal ability have been used. Additionally, the evaluation of single traits has been recorded with different scaling, and the ranking is not always within the full bandwidth of variance. In practice, the implementation of such surveys into routine work faces difficulties, and may reduce the attention to the given behaviour notes. It is very important to develop tests which can be easily introduced into practical management without extra time for acquisition and labour. The video analyses used in our study are not feasible on farms. Especially the continuous evaluation is only possible on research farms, as long as no advanced techniques such as video analysis with automatically image recognition are available. One conceivable approach is documentation with time-sampling rates and the automated assessment of posture patterns, used in an early warning system (Cornou, et al., 2008). For instance, Oliviero et al. (2008) described differences in behavioural patterns around farrowing as a tool for automatic parturition control. Human supervision at farrowing can reduce perinatal piglet mortality by half (Oliviero et al., 2008), but high costs for working hours are required. Besides the measuring of body temperature and respiratory rates, the assessment of different movements can provide more details for effective work organisation (Oliviero et al., 2008). A further future approach could be the registration of prepartal behavioural patterns in sows via sensors, possibly integrated in the earmark, similar to pedometers in cows. The measurement of pressure distribution on the lying surface of the crate represents another attempt at an early warning system, perhaps integrated in a MIS (management information system). Another type of analysis is animal vocalisation, which allows the interpretation of stress patterns in a non-invasive way (Manteuffel et al., 2004). It may be used to assess animal welfare as well as health status and social adaptation. Audio information was not collected on the time-lapsed video records in our study. However introducing automatically audio measurements in practice to identify diseased sows could be an option for future research.
References


This thesis focused on the behavioural background of sows and the relationship to crushing piglets. In particular, the locomotory and the responsive behaviour of sows towards their piglets and the impact of the piglets’ activity were analysed. Behavioural tests were performed to investigate and evaluate various important behavioural traits.

The behavioural elements of ‘nest-building’ behaviour of the sows were presented in chapter one as a review. ‘Nest-building’ is an important part of maternal behaviour strongly related to reproductive abilities in sows. Pre-farrowing behavioural patterns are mainly characterised by ‘nest-building’ activities, resulting in a nest that provides shelter for the piglets. In the course of domestication, sows have not lost their innate behaviour to build a nest and perform at least elements of it when appropriate space and materials are available. The possibilities to perform ‘nest-building’ can be restricted to different extents in commercially farmed pigs. Although they are kept in different modern housing systems, sows need ‘nest-building’ performance as part of the natural behavioural patterns. With regard to the increased demands for animal welfare and following changes in the legislation for pig husbandry, possible consequences for different housing systems were discussed.

The following chapters were based on the same data. The present dataset was recorded in a nucleus herd of the German Breeding company ‘Hülsenberger Zuchtschweine’ for one year and consisted of 438 litters recorded from 386 pure-bred German Landrace sows. All sows were videotaped continuously starting 12 hours ante partum until 48 hours post partum. From the population, sows were randomly sampled in a block data design considering different matching criteria (number of piglets born alive, parities and farrowing date). Forty sows were compared: twenty sows that crushed more than one piglet (C-sows) and 20 sows that crushed none (NC-sows). Locomotion behaviour traits were analysed to frequency, duration and manner.

The relationship of crushing piglets to posture patterns of sows was investigated in chapter two. Definite traits of sows positions (‘lying–down’, ‘standing-up’ behaviour), posture changes, speed, manner and frequencies of movements were analysed. These traits were calculated according to the difference between NC-sows and C-sows. Results revealed that prepartum, NC-sows performed more restlessness while performing movements such as...
‘standing’ or ‘sitting’. Primiparous C-sows were less ‘active’ than primiparous NC-sows. NC-sows showed a longer duration of ‘nest-building’ behaviour per hour as well as higher frequencies of ‘nest-building’ behaviour per hour before farrowing. Post partum ‘rolling movements’ were shown more often in primiparous C-sows. Additionally, C-sows preferred ‘ventral recumbency’ within ‘rolling movements’ and as the final position of ‘lying-down’ behaviour. NC-sows performed ‘lateral recumbency’ more often and much longer as the final position of ‘lying-down’ behaviour. Furthermore, especially multiparous C-sows’ bouts of ‘sitting’ behaviour were much longer than those of multiparous NC-sows. These results suggested that different behavioural patterns, especially ‘nest-building’ behaviour prepartum and ‘ventral-’ or ‘lateral recumbence’ post partum, are possibly useful to characterize good maternal abilities of sows to minimise crushing piglets.

In chapter three, traits of ‘pre-lying’ behaviour of sows were analysed in relationship to crushing piglets, as well as the times of ‘resting-activity’ cycles of the offspring and their location with regard to the sow. The postural behavioural traits of sows and elements of ‘pre-lying’ behaviour were analysed according to frequencies, duration, manner and combination of other positions (e.g. ‘nosing’ and ‘looking around’ before ‘lying-down’). These traits were calculated according to the difference between NC-sows (NC-piglets) and C-sows (C-piglets). Results revealed post partum, primiparous NC-sows performed ‘sniffing’ as an element of ‘pre-lying’ behaviour with longer durations and significantly more often than primiparous C-sows, especially before ‘kneeling on front legs’ followed by ‘lateral recumbent’. Furthermore, multiparous NC-sows performed the trait ‘looking around’, followed by ‘lying-down’ with ‘kneeling on front legs’ more frequently than multiparous C-sows. Additionally, the NC-sows ‘looked’ more often towards the piglet nest site. The trait ‘nosing’ was performed by primiparous NC-sows more often than by primiparous C-sows. The trait ‘looking around’, followed by ‘nosing’, was performed more frequently by NC-sows than by C-sows. However, the duration of ‘sleeping’ and the ‘activity’ behaviour beginning and ending at the mammary gland were significantly longer in C-piglets. This study suggested that traits of ‘pre-lying’ behaviour of NC-sows and C-sows were performed differently, showing large variations in the way the piglets’ attention was demanded before the sow finally lay down. Therefore ‘sniffing’, ‘nosing’ and ‘looking around’ as components of ‘pre-lying’ behaviour represent possibly useful traits to determine the maternal responsiveness of sows.
Different behavioural traits of posture patterns of sows were analysed in combination with several behaviour tests in chapter four. The postural behavioural traits were assessed according to duration and frequencies of positions and analysed separately pre- and post partum. In three different behaviour tests (SEPD1, SEP21, SCREAM), the sows’ maximum reaction was evaluated and classified into test scores from score 1 (no reaction) to score 5 (very strong reaction). With regard to different behavioural traits, results indicated heterogeneous correlations in different behavioural tests. In SEPD1, sows with a high test score showed tendentially more often behavioural patterns, except of bouts of ‘resting’ behaviour. Positive correlations of ‘activity’ behaviour and ‘nest-building’ behaviour prepartum were found in sows’ reaction in SEPD21. Post partum ‘resting’ behaviour in general was positively correlated as well as ‘nosing’ behaviour in SEPD21. Furthermore, a high test score in SCREAM was positively correlated with durations and frequencies of different behavioural traits, except of ‘resting’ behaviour in general prepartum and ‘nosing’ behaviour post partum. These results revealed that behavioural tests heterogeneously correlated with posture patterns of sows. Thus, it is difficult to determine maternal behaviour, expressed by behavioural traits, via behavioural tests.

Differences between the traits to characterise the maternal behaviour of sows with regard to piglet crushing exist, in particular in locomotory behavioural patterns. These differences could be used in further research as targets in genetic or environmental approaches to improve maternal behaviour in sows and to reduce the pre-weaning mortality of piglets.
ZUSAMMENFASSUNG


Auf die Beziehungen zwischen erdrückten Ferkeln und den Bewegungsmustern der Sauen wird im zweiten Kapitel eingegangen. Dies erfolgt durch die Analyse definierter Merkmale der Sauen in bestimmten Positionen, wie dem Verhalten beim Ablegen oder Aufstehen. Darüber hinaus werden die Bewegungsänderungen, die Schnelligkeit, die Art und Weise sowie die Häufigkeiten der Bewegungen berücksichtigt. Die Auswertung erfolgt über die Differenzbildung zwischen den einzelnen Passer-Paarungen bezüglich der aufgezählten Merkmale.


ihren Passern, häufiger umschauen vor dem ,Ablegen auf das Karpalgelenk’ und auch vermehrt in Richtung Ferkelnest blicken. Im Gegensatz dazu kann die Merkmalskombination ,Umsehen’ gefolgt von ,Rüsseln’ häufiger bei den C-Sauen beobachtet werden.

Die Dauer der Schlafzeit und der Aktivitätszeit der Ferkel direkt am Gesäuge der Sau ist bei den C-Ferkeln länger als bei den NC-Ferkeln. Zwischen NC-Sauen und deren Passern bestehen unterschiedliche Ausprägungen im Einfordern der Aufmerksamkeit der Ferkel vor dem Ablegen. Daher sind ,Schnüffeln’, ,Rüsseln’ und ,Umsehen’ als bedeutende Verhaltenskomponenten vor dem Ablegen einzuordnen und können möglicherweise sinnvoll eingesetzt werden, um die mütterliche Fürsorge genauer zu definieren.


Abschließend ist festzuhalten, dass die unterschiedlichen Merkmale eine Charakterisierung des maternalem Verhaltens von Sauen ermöglichen. Dies gilt insbesondere für das
Bewegungsverhalten der Sauen im Zusammenhang mit erdrückten Ferkeln. In weiteren Forschungsprojekten könnten diese Unterschiede gezielt genutzt werden, um Ansätze weiter zu verfolgen, die auf genetischer oder umweltbedingter Basis die Muttereigenschaften von Sauen verbessern und die Ferkelsterblichkeit vor dem Absetzen reduzieren.
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