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# Loose farrowing systems: challenges and solutions

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## Abstract

*The use of farrowing crates is increasingly questioned from an animal welfare point of view. Even so, since a number of attempts to develop loose farrowing systems have been unsuccessful, leading to high levels of piglet mortality due in the main to crushing, many farmers remain sceptical as to whether or not alternative systems can be viable. On the other hand, several European countries have introduced legislation requiring loose farrowing systems, thus promoting research into this type of housing and allowing for performance studies based on large samples of commercial farms. As a consequence of these recent developments, we think it timely to reconsider the evidence available on loose farrowing systems. In our review, we first address the normal peri-parturient behaviour of domestic pigs, as well as studies comparing behaviour and stress physiology in sows kept in both crates and loose systems during farrowing. We then review approaches taken to develop alternative farrowing systems in different countries, and focus lastly on pen, piglet and sow characteristics that contribute to piglet survival in loose farrowing systems. Taking scientific evidence as well as practical experience into account, we conclude that piglet mortality in loose farrowing systems need not exceed that of crate systems. To obtain good performance results, sows due to farrow should be kept individually in sufficiently large pens, structured for preference into a nest area and an activity area. Furthermore, both management and breeding aspects, resulting in high piglet viability and good maternal behaviour, are essential to achieve high production in loose farrowing systems.*

**Keywords**: *animal welfare, behaviour, farrowing sow, legislation, pen design, piglet mortality*

## Introduction

The peri-parturient behaviour typical of domestic breeds of sow can be characterised by four consecutive stages, namely: isolation-seeking behaviour; nest-site selection; nest-building behaviour and post-parturient maternal behaviour. Farrowing crates, introduced in the pig industry in the early 1960's (Robertson *et al* 1966) to improve space utilisation by reducing space requirements per sow while, simultaneously, preventing high levels of piglet mortality due to crushing by the sow, not only restrict the sow's freedom of movement but also impair her ability to choose a nest site, perform nest-building behaviour and establish physical contact with the piglets (Arey 1997; Scientific Veterinary Committee 1997; Barnett *et al* 2001). Consequently, the implications of using farrowing crates from an animal welfare perspective have been addressed (Baxter 1982; Fraser & Broom 1990; Wechsler *et al* 1997).

Over the last 25 years, several attempts have been made to develop alternative housing systems and introduce them on commercial farms (eg Baxter 1991; Phillips & Fraser 1993; Schmid 1993; Cronin *et al* 2000). Despite this, several of the proposed alternative farrowing systems fell short of success in experimental testing, due mainly to problems of piglet mortality (eg Marchant *et al* 2000; Pedersen *et al* 2006). Throughout the present paper, the term piglet mortality is used as a synonym for postnatal mortality of liveborn piglets prior to weaning. As the percentage of piglets dying during this period is critical not only in an economic sense but also in terms of animal welfare, overall assessments of the advantages and drawbacks of loose farrowing systems in comparison to farrowing crates did not tend to rule clearly in favour of the former. For example, the Scientific Veterinary Committee (1997) of the European Community concluded that the extent to which sow welfare in farrowing crates is impaired requires further elucidation, while also recommending that further development of farrowing systems, in which the sow can be kept loose and carry out normal nest building without any compromise to piglet survival, should be strongly encouraged. Similarly, Barnett *et al* (2001) stated that piglet mortality in loose farrowing systems needs to match that of farrowing crates, in order for the former to be recommended.

There are, however, recent publications showing that loose farrowing systems can be as successful as farrowing crates in terms of piglet survival (eg Cronin *et al* 2000; Weber 2000; Weber *et al* 2007), and several new studies have addressed specific aspects of loose farrowing systems that, if considered, can help to prevent increased levels of piglet mortality (eg Rantzer & Svendsen 2001; Grandinson *et al* 2003; Tajet *et al* 2003; Andersen *et al* 2005; Weber *et al* 2006). Evidence emerging from these recent publications is likely to play a significant role in enhancing the success rate of loose housing systems used in label production (eg organic farming), as well as promoting further development of animal welfare legislation regarding farrowing systems. For example, European Union Council Directive 2001/88/EC, which lays down minimum standards for the protection of pigs, stipulates that the use of farrowing crates be reconsidered on the basis of a report covering further developments of loose-house systems for farrowing sows, to be finalised by the end of 2007.

The aims of this paper are: 1) to give a brief outline of the normal peri-parturient behaviour of domestic pigs; 2) to summarise the results of studies into the behaviour and stress physiology of sows kept in both farrowing crates and loose farrowing systems; 3) to review the development of alternative farrowing systems with special focus on piglet mortality, and 4) to address studies elucidating factors that may have a major impact on performance in loose farrowing systems. Given that the introduction of farrowing systems is not only a consequence of scientific evidence but also of political intervention, the review paper also addresses legislation concerning the use of farrowing systems in different countries.

## Peri-parturient behaviour of domestic pigs kept in semi-natural enclosures

The normal peri-parturient behaviour of sows of domestic breeds has been studied extensively in pigs kept in semi-natural enclosures both in Scotland (Stolba 1984; Stolba & Wood-Gush 1984, 1989) and Sweden (Jensen 1986, 1989; Jensen *et al* 1987) in the late 1970's and early 1980's. Furthermore, there are several studies describing peri-parturient behaviour in feral populations of domestic pigs in the USA (Kurz & Marchinton 1972; Barrett 1978; Mauget 1981; Graves 1984; Mayer *et al* 2002). The behaviour reported from these different study sites is much the same, and also very similar to the peri-parturient behaviour observed in the domestic pig's ancestor, the wild boar (Gundlach 1968; Buss 1972; Martys 1982), indicating that there is a strong genetic basis for peri-parturient behaviour.

On the day prior to farrowing in a semi-natural enclosure, the sow will separate herself from the social group and seek a suitable nest site away from her group's communal nest and feeding site (Stolba & Wood-Gush 1984; Jensen 1986). Typically, she will select a nest site providing natural shelter, such as tree branches or bushes, while also allowing an open view of the surroundings (Stolba & Wood-Gush 1984; Jensen 1986). In the last few hours before farrowing, she will exhibit intense nest-building behaviour, first excavating a hollow and then gathering grass as well as leaves and twigs from a distance of up to 50 m from the nest site (Stolba 1984; Jensen 1986; Stolba & Wood-Gush 1989). Based on factor analyses of nest-building behaviour, Jensen (1993) and Jensen *et al* (1993) concluded that the onset of nesting motivation is most likely triggered by mainly internal factors, whereas the course of nest building and the material-oriented behaviour depends strongly on external factors, such as the degree of protection afforded to the nest site and the availability of materials. Climatic conditions also seem to have a role to play, as more nesting material tends to be gathered in winter than in summer (Jensen 1989). When finished, the nest is round-to-oval in shape and may consist of several plant species that were readily available in the vicinity of the nest site (Jensen 1986; Mayer *et al* 2002). The nest will contain enough material to cover the piglets completely, and in some cases the sow as well (Jensen 1989). While farrowing the sow will stand up and sniff her piglets (Jensen 1986; Petersen *et al* 1990). During the first few days after birth, the piglets will remain chiefly in the nest, and the sow will only leave for brief periods (Jensen 1986; Stangel & Jensen 1991). When the piglets are approximately 5 days old, they start to follow the sow regularly on her excursions (Stolba 1984; Jensen 1986; Stangel & Jensen 1991). Finally, the sow will abandon the nest site when the piglets are about 10 days old and join the other sows from her group (Jensen & Redbo 1987). Natural weaning is a gradual process that finishes when the piglets are about 12 to 17 weeks old (Stolba 1986; Jensen & Recén 1989).

## Comparison of the welfare of sows housed in crates and pens

### Behaviour restrictions of crated sows around farrowing

The final 48 hours that precede parturition sees an increase in sitting and standing activity for sows kept both in crates and in pens (loose housing) (Hansen & Curtis 1980). Moreover, if sows are given access to extra space for locomotion outside the farrowing pen, the distance they walk in the period from 11 to 4 hours prior to parturition is significantly higher than in previous days (Haskell & Hutson 1994), and they are also more motivated to lift a lever in order to gain access to space for moving around, the day before farrowing (Haskell *et al* 1997). Farrowing crates thus impair the sow's ability to move around over a period of time characterised by increased activity levels.

The crating of sows that are due to farrow also precludes selection of a nest site. When given a choice in a loose housing system, they will favour pen areas covered with straw bedding (Arey *et al* 1992) and choose nest sites in enclosed areas (Hunt & Petchey 1989; Schmid 1990). Providing an earthen floor at the nest site may not be possible on commercial farms for practical reasons; however, in an experimental study, where sows had free access to a pen area with an earthen floor, the frequency of visits to that area increased on the day before farrowing, and all sows dug a nest and farrowed in it (Hutson & Haskell 1990).



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Several studies have shown that nest-building behaviour, which typically starts about 12 hours prior to delivery of the first piglet (Arey *et al* 1991), is greatly restricted in sows kept in crates as opposed to pens (eg Buchenauer 1981; Troxler & Weber 1989; Hartsock & Barczewski 1997; Damm *et al* 2003a). Moreover, sows kept in crates or tethered redirect elements of their nest-building behaviour to fixtures in their housing system (Lammers & De Lange 1986; Troxler & Weber 1989; Widowski & Curtis 1990; Cronin *et al* 1994; Lawrence *et al* 1994). Using operant conditioning technique, Arey (1992) showed that sows are highly motivated to gain access to straw during the 24 hours before farrowing. In line with this finding, sows increased locomotion significantly on the day before parturition when straw was provided in a hopper away from the nest site (Haskell & Hutson 1996). In an experiment with pre-formed nests presented to sows due to farrow (Arey *et al* 1991), straw-carrying and pawing behaviour was no less than that of sows that had built a new nest from scratch, indicating that the very performance of these activities would seem to play a significant role in reducing nest-building motivation. Hutson (1992) trained sows that were due to farrow to lift a lever in order to gain access to either a box containing straw, a box containing sticks, an empty box or a food drop, and concluded that the intensity of rooting and pawing behaviour for all treatments indicated the presence of a strong motivational requirement to perform nest-building behaviour which appeared independent of external nest-building stimuli. Similarly, Widowski and Curtis (1990) observed that the overall pre-partum activity of sows in pens furnished with straw in a basket, cloth tassel, both, or neither did not differ, suggesting that on the day of farrowing, behaviour patterns directed at nesting material may be important to the sow, even if they do not result in nest construction.

Crating sows during farrowing also impairs their ability to initiate contact with the piglets. Loose-housed sows are regularly observed turning around and sniffing newborn piglets (Weber 1984), but these behaviours are not possible in farrowing crates. Moreover, sows housed in crates have difficulties performing lying-down behaviour (Bonde *et al* 2004), and are forced to defaecate at the nest site, whereas pre-parturient sows, loose-housed in pens, typically urinate and defaecate more in the activity area than in the resting area (Schmid 1992; Schmid & Weber 1992; Damm & Pedersen 2000). Finally, parturition duration has been found to be longer for crated sows than those loose-housed (Weber & Troxler 1988; Klocek *et al* 2000; Thodberg *et al* 2002). Prolonged farrowing may increase the risk of intrauterine asphyxia, resulting in a higher rate of stillborns, and a reduced piglet vitality (Herpin *et al* 2002; Alonso-Spilsbury *et al* 2005).

European Union Council Directive 2001/88/EC requires sows kept in newly built holdings or in those rebuilt since January 2003 to be loose-housed during the majority of the gestation period. As a consequence, loose housing of pregnant sows will become the norm, and subsequent confinement in farrowing crates may have an even greater impact on their welfare. Boyle *et al* (2000) compared behaviour, heart rate and skin lesion scores of gilts in farrowing crates that had been loose-housed in bedded or unbedded pens or kept in crates during the gestation period, and concluded that gilts from both loose treatments experienced greater distress upon introduction to the farrowing crate.

## Indications of stress in crated sows around farrowing

Farrowing crates not only have an effect on sow behaviour but also on indicators used typically to assess stress such as heart rate and cortisol concentration. Damm *et al* (2003a) reported that sows kept in crates had higher heart rates than loose-housed sows during the final hour preceding farrowing. In studies comparing plasma cortisol concentrations in sows kept in crates without access to straw and in sows housed in pens with straw bedding, elevated levels were found during the pre-parturient period (Lawrence *et al* 1994; Jarvis *et al* 1997, 2001). When the effects of housing system and availability of straw were varied separately, primiparous sows housed in crates were shown to have higher hydrocortisone levels than those housed in pens, regardless of straw availability; an effect particularly pronounced at the peak of nest-building activity (Jarvis *et al* 2002). Finally, the importance to sow welfare of having the opportunity to construct a nest is also emphasised by the fact that both heart rate and plasma cortisol levels were raised in primiparous sows housed in pens that had nests removed experimentally 10 hours after the onset of nest building and again every 4 hours until parturition, compared to sows subjected to sham removals of their nests (Damm *et al* 2003b).

## Effects of crates on sow and piglet welfare during lactation

Contrary to the extensive literature available on the peri-parturient behaviour of sows in both crates and pens, few studies have so far addressed the welfare of sows and piglets during subsequent lactation. Regarding stress physiology, Cronin *et al* (1991) reported that plasma cortisol concentrations were higher in sows kept in crates than in those housed in pens (loose-housed) on day 28 of lactation, but did not differ between the two treatments on days 1, 7, 14 and 21. Measuring cortisol concentrations during days 1, 2 and 7 of lactation, Lawrence *et al* (1994) found no significant differences in stress levels between primiparous sows confined to farrowing crates and those loose-housed. Similarly, Jarvis *et al* (2006) reported that baseline plasma ACTH and cortisol levels on days 2, 8, 15, 22 and 29 post-partum did not differ between primiparous sows kept in crates and pens. By day 29, however, cortisol levels following CRH challenge (measured as an indicator of chronic stress) were higher in sows housed in crates, suggesting that prolonged confinement in farrowing crates may have a negative impact on sow welfare.



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Some general aspects of housing conditions in crates do not change over time, however, and may thus adversely affect sow welfare throughout lactation. Freedom of movement is generally restricted (Buchenauer 1981; Weber 1984), and sows often bump parts of their body against the sides of the crate when lying down or standing up (Troxler & Weber 1989; Harris & Gonyou 1998). Bonde *et al* (2004) reported that lying-down-behaviour problems were associated with injuries in sows housed in farrowing crates in commercial herds. Similarly, Boyle *et al* (2000) found increases in the skin lesion scores of primiparous sows after 24 hours in the crate, and observed further increases post-farrowing. Moreover, Boyle *et al* (2002) showed that with sows kept in farrowing crates the prevalence of wounds on different parts of the limb continued to be higher than pre-farrowing, until weaning took place.

Lactating sows kept in pens typically leave the nest area to urinate and defaecate (Bertschinger *et al* 1990; Schmid 1992; Pajor *et al* 2000), whereas sows confined in crates are forced to excrete at the nest site. Moreover, the ability of loose-housed sows to choose between different areas in a pen for lying down may favourably influence their ability to thermoregulate, as sows increasingly prefer to lie on a cool floor during the course of lactation (Phillips *et al* 2000). In addition, crated sows are unable to approach the piglets should they wish to, and, depending on the design of the crate and its position within the pen, piglets may also experience difficulty gaining access to the udder during suckling periods (Fraser & Thompson 1986; Thompson & Fraser 1986; Weber 1987). As far as the effects crates have on suckling behaviour, Buchenauer (1981) found that suckling occurred less frequently in a loose housing system than in a crate system. Similarly, Arey and Sancha (1996) reported that suckling bouts were less frequent but of longer duration in a loose farrowing system compared with a farrowing crate, whereas Cronin and Smith (1992a) observed no difference in the number of suckling bouts between pens and crates. Finally, confinement of lactating sows also has an influence on incidences of abnormal behaviour; sows kept in farrowing crates show higher levels of oral/nasal stereotypies than loose-housed sows (Weber 1984; Damm *et al* 2003a).

As farrowing crates are not usually provided with litter (Scientific Veterinary Committee 1997), housing conditions are quite barren for the piglets too, which may have long-term effects on their behaviour. De Jonge *et al* (1996) found that piglets raised in a sparse environment (including a standard farrowing crate) behaved more aggressively than piglets from an enriched (outdoor) environment when housed in pairs after weaning, with the subordinates of these pairs developing symptoms indicative of chronic social-stress exposure. With regard to learning ability, Sneddon *et al* (2000) reported that pigs raised in enriched environments (including a loose farrowing pen with straw-bedding from day 3 post-partum until weaning) up to an age of 14 weeks, learned both an operant task and a maze task more rapidly than their counterparts from barren environments (including a crate farrowing system).

### Legislation concerning the use of farrowing crates in different European countries

Although the Scientific Veterinary Committee (1997) of the European Community concluded that it is beyond doubt that pre-parturient sows have an internally triggered need to express nest-building behaviour and that all farrowing crates are similar in that they obstruct the full expression of normal nesting behaviour, current EC legislation does allow for the use of farrowing crates, whereas the crating of dry sows is to be banned after a transitional period lasting until the end of 2012. Legislation in Sweden, however, prohibits the use of conventional farrowing-crate systems, and the sow's freedom of movement may only be restricted if she displays aggressive or abnormal behaviour constituting an apparent risk of injury to the piglets, and only during the piglets' first few days of life (Yngvesson personal communication 2006). Similarly, Norwegian farmers are generally not permitted to use farrowing crates, but particularly restless sows may be confined for a maximum of seven days after farrowing (Bøe personal communication 2006). In Switzerland, farrowing crates were subjected to testing with regard to animal welfare in the course of the compulsory authorisation procedure for mass-produced housing systems and equipment (Wechsler 2005). As a result of this testing, the Swiss Animal Protection Regulations were revised in 1997. It is now stipulated that farrowing pens must be designed to provide sufficient space for the sow to turn around freely. Only in exceptional cases (leg weakness, savaging of piglets) may the sow be confined to a crate while giving birth. Conventional farrowing crates must have been replaced on all farms by the end of June 2007. Finally, loose farrowing systems are important in organic farming. The European Union Council Regulation 1804/1999 on organic production of agricultural products states that "housing conditions for livestock must meet the livestock's biological and ethological needs (eg behavioural needs as regards appropriate freedom of movement and comfort)" and that "all mammals must have access to pasturage or an open-air exercise area or an open-air run"; requirements that are not compatible with the use of farrowing crates.

## Alternative farrowing systems: developments and performance results

### The piglet mortality problem

Piglet mortality can be a major problem in alternative farrowing systems as well as in conventional farrowing crates, and crushing by the sow, occurring mainly during the first 3 days after birth, accounts for a significant proportion of pre-weaning piglet mortality (English & Morrison 1984; Svendsen *et al* 1986; Dyck & Swierstra 1987; Kunz & Ernst 1987; Weary *et al* 1996a; Marchant *et al* 2000, 2001; Edwards 2002; Jarvis *et al* 2005; Pedersen *et al* 2006).



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Schmid (1990) and Schmid and Hirt (1993) described in detail the lying-down behaviour of sows in loose farrowing systems, addressing several mechanisms in the behaviour of the sow and piglets that have probably evolved to minimise piglet mortality due to crushing. Upon entering the nest site, the sow will typically make snout contact with one or more of her piglets and root in the nesting material, possibly to advertise her presence to the piglets. She will then initiate lying-down behaviour, standing on the carpals of one or both forelegs with her hindquarters still in the standing position. At this point, the piglets have a clear tendency to group themselves on one side of the sow, and the sow will in most cases lie down with her hindquarters to the side opposite the piglet group. If, despite all this a piglet is still too close to the sow's body and at risk of being crushed, it will often react with a reflex-like jump to the side. When a piglet is trapped and wholly or partially covered by the sows' body, it moves fiercely in an attempt to free itself, and also vocalises intensely. In response to the movements and screams of the piglet (or playbacks of piglet distress calls: Cronin & Cropley 1991; Hutson *et al* 1992) the sow often shifts from a lying to a sitting or standing position, thus enabling the piglet to remove itself from danger. In line with these observations, Blackshaw and Hagelsø (1990) reported that sows in a loose farrowing system typically rooted vigorously before lying down, and lay down carefully for the first 8 days after parturition. In this study, nose-contact behaviour with the piglets was only rarely associated with lying down, and was thus not considered to be an action of the sow ensuring that the piglets were out of the way. Marchant *et al* (2001), however, observed that events during lying-down movements of the sow that posed a danger to the piglets were more likely to occur when the sow lay down without carrying out much piglet-directed pre-lying behaviour, and concluded that co-ordination of behaviour between the sow and her litter is vital to reduce the risk of piglet crushing.

Despite these mechanisms, crushing can be a major disadvantage of loose farrowing systems. Situations in which the sow lets her hindquarters fall to one side instead of lowering them vertically, or in which the lying sow rolls her body longitudinally from a vertical to a lateral position, were found to be especially dangerous in terms of the likelihood of crushing piglets (Wechsler & Hegglin 1997). Similarly, Weary *et al* (1998) reported that lying down from a standing position and rolling from lying on the udder to lying on the side caused most of the crushing in a loose farrowing system, and Marchant *et al* (2001) observed that rolling accounted for a higher-than-expected proportion of crushing deaths. Such movements also occur in conventional farrowing crate systems, but may be of more significance in the crushing of piglets with loose-housed sows. For example, Weary *et al* (1996a) observed that rolls from the side to the udder and from the udder to the side were more frequent in pens than in crates, and that rolling movements from the udder to the side were typically faster in pens than in crates.

## From pens to crates and back

An early comparison of the performance of sows kept in crates or loose-housed for farrowing was made by Robertson *et al* (1966). At that time, the loose farrowing system was labelled the 'conventional system' and compared to the newly introduced 'stall system'. It was found that piglet mortality was lower (18.6 vs 26.5%; 150 farrowings in total) and piglet weight at weaning (occurring at 8 weeks of age at that time) higher in the stall system. Moreover, the number of piglet deaths caused by crushing was higher in the conventional system. Studies like this supported the spread of the farrowing crate in the pig industry. For example, Hendriks *et al* (1998) reported that 92% of all sows in 14 European countries were housed in crates for farrowing.

In the 1980's, however, studies on the normal peri-parturient behaviour of sows of domestic breeds kept in semi-natural environments (Stolba & Wood-Gush 1984, 1989; Jensen 1986, 1989) as well as investigations into the disturbance of sow behaviour by confinement at farrowing (Buchenauer 1981; Baxter 1982) gave rise to questions concerning the welfare of sows kept in farrowing crates, and prompted research into the development of alternative farrowing systems (Phillips & Fraser 1993; Arey 1997; Edwards & Fraser 1997).

An early Danish study (Hansen & Vestergaard 1984), comparing the performance of four groups of sows (70 farrowings in total; Vestergaard & Hansen 1984) which were either neck-tethered or loose-housed during pregnancy and during farrowing, yielded promising results. Piglet mortality up to the age of 56 days (weaning) was significantly lower in sows housed in loose farrowing systems (10.9%) compared to tethered sows (17.2%). Similarly, Weber (1984) presented results of a Swiss investigation showing that piglet mortality in a loose farrowing system (23.0%; 23 farrowings) was significantly lower than in a conventional crate (30.1%; 53 farrowings). As a consequence, research into alternative farrowing systems was continued in Switzerland (Schmid 1992; Schmid & Weber 1992; Friedli *et al* 1994). Weber (2000) summarised the results of several Swiss studies and compared the performance of sows kept in farrowing crates (127 farrowings) to that of sows kept in four different loose-farrowing systems (134, 45, 45 and 57 farrowings, respectively). Although piglet mortality did not differ significantly between sows confined in crates (15.7%) and sows loose-housed in the alternative farrowing systems (13.9, 13.5, 15.2 and 11.3%, respectively), the causes of piglet mortality were different. In loose farrowing systems, a higher percentage of piglets were crushed, whereas the loss rate due to runts (piglets with a low birthweight or that did not grow well) was higher in the farrowing crates. A possible explanation for this difference is that in farrowing systems with loose-housed sows, piglets weakened from low birthweight or health problems have a higher risk of being crushed.



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In the UK, Baxter (1991) developed a group farrowing system for six sows, in which the sows had individual farrowing nests and a communal activity area. In a prototype version of this 'freedom' farrowing system, piglet mortality came to 12% (40 farrowings). Bradshaw and Broom (1999) tested a loose farrowing system consisting of an oval pen where the sow farrowed and an adjacent rectangular resting area to which the sow had access, but from which the piglets were excluded up to the age of 9 days. On the basis of a small sample size, they found that piglet mortality – the majority of which was due to crushing – was significantly higher in the oval pen (8 farrowings) compared with a farrowing crate (10 farrowings). Marchant *et al* (2000) compared piglet mortality in two group farrowing systems with that in a standard commercial crate. The group farrowing systems consisted of either five individual pens or five farrowing crates within individual pens, with the sow able to walk through the crates. In both of these loose farrowing systems, sows had access to communal passageways and an outdoor dunging area, while the piglets were contained within the pen up to the age of approximately 7 to 10 days. Piglet mortality was considerably higher in the two loose farrowing systems (25 and 26%; 70 and 60 farrowings, respectively) than in the crate system (13%; 70 farrowings).

Again in the UK, approximately 30% of the national sow-breeding herd is housed outdoors (Edwards 2005), and loose housing is the normal type of farrowing system used in outdoor pig production. Based on a survey of 77 outdoor breeding units sited throughout the country, Abbott *et al* (1996) reported that average pre-weaning mortality stood at 12.1%, which was similar to the average piglet mortality in UK commercial herds at the time (Edwards 2002). In France, an analysis of performance results of the French national herd (data from 1994) showed the percentage of piglet losses to be 21.1% for outdoor herds, as compared to 17.4% for indoor herds (Berger *et al* 1997).

As reviewed by Edwards and Fraser (1997), several attempts were made in various European countries in the early 1990's to develop farrowing systems in which sows were kept in groups during the peri-parturient period and throughout lactation. These systems, however, were unsuccessful for several reasons. Firstly, sows displayed aggressive behaviour towards one another during the nest-building period (Götz & Troxler 1993, 1995a,b; van de Burgwal-Konertz 1996), thus putting the idea of group housing for the peri-parturient period into question. Secondly, there were difficulties with nest-site acceptance, with sows occasionally giving birth to some or all of their piglets in the communal areas of the group housing system (van Putten & van de Burgwal 1989; Buré & Houwers 1993; van de Burgwal-Konertz 1996). Thirdly, there were problems regarding the timing of piglets leaving the nest site. If the site was abandoned too soon after birth there was a risk of high levels of cross-suckling, resulting in injuries to mainly the heads of the cross-sucklers, and in the reduced performance of such individuals (Götz & Troxler 1993, 1995a,b; van de Burgwal-Konertz 1996). If, on the other hand, only the sow but not the piglets could leave the nest site during the lactation period, some sows weaned their litters at a very early age (Bøe 1993, 1994).

In the USA, several studies investigated modified crates which allowed the sow to turn around without substantially increasing space requirements. Piglet mortality in these farrowing systems was, in general, moderately low: 9.4% (11 farrowings, mortality up to 21 days of age) in a 'turn-around crate' (McGlone & Blecha 1987); 8.7% (20 farrowings, mortality up to 14 days of age) in the 'Ottawa crate' (Fraser *et al* 1988) and 15.4% (32 farrowings, mortality up to 28 days of age) in an 'ellipsoid crate' (Lou & Hurnik 1994). Low piglet losses were also obtained in small-sized pens with sloped floors, tested by Collins *et al* (1987; 12.4%; 59 farrowings, mortality up to 21 days of age) and McGlone and Morrow-Tesch (1990; 9.1%; 10 farrowings, mortality up to 21 days of age).

In Australia, Blackshaw *et al* (1994) observed markedly higher mortality rates for piglets in a loose farrowing system than in a farrowing-crate system (32 vs 14%; eight farrowings each). Similarly, comparing the performance of primiparous sows kept in crates or loose farrowing pens, Cronin and Smith (1992b) reported that litters in pens tended to have higher pre-weaning mortality than litters in crates (16.5 vs 10.5%; 32 farrowings each). However, in a further recently developed loose farrowing system tested by Cronin *et al* (2000), the Werribee Farrowing Pen, piglet mortality did not differ significantly from that observed in a conventional farrowing crate (15.5 vs 17.5%, 66 and 80 farrowings, respectively). As with the studies reviewed by Weber (2000), there was a tendency for proportionally more piglet deaths to be attributed to crushing by the sow in the loose farrowing system than in the crate system, but proportionally fewer deaths due to the small/weak/non-viable syndrome.

Recently, three studies analysing performance data of fairly large numbers of farms using loose farrowing systems have been published. Based on performance data of 113 Norwegian herds, Tajet *et al* (2003) calculated an average piglet mortality of 14.1%. Of these herds 39 had loose-housed sows between farrowing and weaning, and the proportion of piglets dying before weaning on these farms stood at 15.2%. O'Reilly *et al* (2006) analysed factors associated with pre-weaning mortality on 67 commercial pig farms in England and Wales using a variety of farrowing systems, including indoor crated, indoor loose and outdoor systems. In their final multivariable model, the risk of pre-weaning mortality (median rate over all farms, 10.7%) did not differ significantly between the farrowing systems, but increased with the weaning age of the piglets, which was considerably higher in indoor loose and outdoor farrowing systems than in indoor crated systems. In Switzerland, Weber *et al* (2007) analysed performance data of 482 farms (44,837 farrowings) using farrowing crates and 173 farms (18,824 farrowings) using loose farrowing systems, and



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reported that piglet mortality stood at 12.1%, irrespective of the farrowing system.

## Factors affecting production results in alternative farrowing systems

There is much variation in piglet mortality in loose farrowing pens, both between studies comparing such systems to conventional crates (Fraser 1990; Edwards & Fraser 1997) and within studies comparing the performance of sows kept in loose systems on different farms (Tajet *et al* 2003; Weber *et al* 2006). Thus, factors such as pen design, vitality of the piglets at birth and quality of maternal behaviour may have a great influence on the success of a loose farrowing system on a given farm.

### Pen-related factors affecting performance

A comparison of piglet mortality between studies of different loose farrowing systems with different pen sizes suggests that a minimum size of 5 $m^2$ is advisable to prevent high levels of piglet losses. Testing loose farrowing pens measuring 5 $m^2$ or less, Blackshaw *et al* (1994), Marchant *et al* (2000, 2001) and Kamphues *et al* (2003) found that pre-weaning mortality was markedly higher than in crate systems, whereas piglet mortality did not differ significantly between pens and crates in several studies with larger pens (Cronin *et al* 2000; Weber 2000; Weber *et al* 2007). In a study using the Werribee loose farrowing pen (Cronin *et al* 1998), experimental variation in the size and width of the nest area did not have a significant effect on piglet survival. As pointed out by Blackshaw and Hagelsø (1990), behaviour patterns typically demonstrated by sows prior to lying down and with the possible intention of advertising their presence to piglets, eg rooting vigorously and moving around, can only occur if there is enough space. Similarly, in reviewing the literature on lying-down and rolling behaviour in sows in relation to crushing, Damm *et al* (2005a) concluded that in a loose-housing situation providing space for pre-lying behaviour and a well controlled lying-down sequence is likely to improve piglet survival.

European Union Commission Directive 2001/93/EC requires that "farrowing pens where sows are kept loose must have some means of protecting the piglets, such as farrowing rails". Evidence regarding the impact of such means of protection on piglet mortality in loose farrowing systems is, however, controversial. Tajet *et al* (2003) analysed piglet mortality in relation to pen design in 39 Norwegian herds and reported that pre-weaning mortality was lower in pens with piglet protection bars fixed to the walls, whereas Weber *et al* (2006) did not find such an effect based on data from 99 Swiss farms using loose farrowing systems with or without piglet protection bars. In a preference study on the lying-down behaviour of sows alongside different types of pen walls in a loose farrowing system, Damm *et al* (2006) observed that sows chose to use a wall with a piglet protection rail less than a plain or sloping wall.

McGlone and Morrow-Tesch (1990) found that more piglets were crushed and fewer piglets were weaned when the loose farrowing system had a level as opposed to a sloped floor (8% slope), and hypothesised that reduced piglet mortality in sloped pens may be attributable to changes in sow resting posture. Collins *et al* (1987) compared loose farrowing pens with floors that had an even greater slope (10 vs 17%), and found no significant difference in piglet mortality. In most loose farrowing systems in use today, however, the slope of the floor is no more than 5%, so as to ensure that liquid flows off. Again, with regard to flooring, Rantzer and Svendsen (2001) investigated the effect of slatted versus solid floors in the dung area of loose-farrowing pens. Pen hygiene was better in the slatted-floor pens and pre-weaning mortality was significantly higher in the solid floor treatment group, due primarily to a higher incidence of traumatic injuries and losses owing to infection. Malmkvist *et al* (2006) compared piglet losses in a loose farrowing system with and without the use of pen-floor heating from 12 hours after onset of nest building until 48 hours after the birth of the first piglet, and reported that liveborn mortality was significantly reduced in the first week after parturition in the treatment with floor heating. Finally, comparing loose farrowing pens with either concrete or plastic-coated expanded-metal flooring, Weary *et al* (1998) found floor quality to have no significant impact on the total number of crushing deaths.

Provision of environmental stimuli in the peri-parturient period has been shown to have a positive effect on maternal behaviour and to reduce piglet crushing. Herskin *et al* (1998) housed sows in loose-farrowing pens with either a concrete or sand floor and with or without a straw feeder, and found that a lower proportion of sows with access to sand, straw or both stimuli crushed piglets by rolling. Moreover, a higher proportion of sows with access to both stimuli responded by standing up during the playback of a piglet distress call. In a further study concerning the quality of nesting material in a loose farrowing system, Damm *et al* (2005b) either provided or did not provide sows with long-stemmed straw in addition to chopped straw. Maternal behaviour related to the crushing of piglets did not, however, differ significantly between the treatments, and the quality of nesting material had no significant impact on overall piglet mortality and mortality due to crushing.

### Influence of piglet- and sow-related factors

Malnutrition, low birthweight, malformations or diseases may result in weakened piglets that are either slow to react or do not react at all to the sow's body movements. As a consequence, such piglets are more likely to be crushed than healthy piglets (Svendsen *et al* 1986; Fraser 1990; Marchant *et al* 2000; Edwards 2002). Large sows seem to be more likely to crush piglets, resulting in a significant effect of parity on the number of piglets crushed both in farrowing crates (Kunz & Ernst 1987) and in loose farrowing systems (Weary *et al* 1998; Weber *et al* 2007). Moreover, litter size at birth has a significant effect on piglet losses due to



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crushing, with more piglets crushed in larger litters (Weary *et al* 1998; Jarvis *et al* 2005; Weber *et al* 2007). This effect may be due to higher within-litter variation in piglet birthweight in larger litters (Quiniou *et al* 2002), which has been shown to be associated with increased liveborn mortality (Marchant *et al* 2000). Alternatively, the effect of litter size can be explained by the fact that there are potentially more piglets that might be crushed, and that there is an increased probability of individual piglets not gathering with the rest of the litter before the sow lies down. Finally, Edwards (2002) stressed that deaths of liveborn piglets attributed to crushing and starvation are often due to the effects of perinatal hypothermia, with rectal temperature decline after birth being more pronounced in lightweight piglets than in heavier ones (Hoy *et al* 1995). Selection for increased survival at farrowing based on information on piglet birthweight, average birthweight in litter, and deviation from average birthweight in litter may thus hold promise for reducing losses due to crushing in loose farrowing systems (Knol *et al* 2002; Mesa *et al* 2006). Interestingly, Leenhouwers *et al* (2002) found a strong positive relationship between foetal cortisol concentration at day 111 of gestation and genetic merit for piglet survival and hypothesised that piglets with higher serum cortisol levels may have an improved ability to cope with hazards during the first few days of life.

In addition to the weight and health of the piglets, the physical condition of the sow is also crucial in piglet survival. For example, heavy sows as well as sows with poor leg health may have difficulty lying down carefully. Furthermore, sow illness is likely to have both direct and indirect effects on the piglets' risk of crushing. It may affect the sow's response to trapped piglets' distress calls, and, if accompanied by reduced milk production, could induce the piglets to spend more time in the high-risk area near the sow (Weary *et al* 1996b). Continued lack of an adequate milk supply will render the piglets weak and inactive, and crushing must be considered the secondary cause of death for such individuals in a loose farrowing system.

Wechsler and Hegglin (1997) suggested that individual differences in sow behaviour may account for differences in piglet mortality in loose farrowing systems. Observing the behaviour of loose-housed sows and their litters during parturition and over the following 10 days, they found that the percentage of liveborn piglets for which crushing was the primary cause of death correlated significantly with both the incidence of behaviour likely to result in crushing shown by a given sow, and her responsiveness to piglet distress calls played back immediately after lying-down behaviour was performed at the nest site. In line with these findings and based on a factor analysis of maternal behaviour, Spinka *et al* (2000) concluded that 'calmness' (including low frequency of major posture changes and cautious lying-down behaviour in the sow) and 'protectiveness' (including high loadings of reaction scores to playbacks of piglet distress calls) were two of the three factors explaining much of the observed variability in sow behaviour. Furthermore, Thodberg *et al* (2002) observed a high level of repeatability across parities of behaviours which were likely to increase the risk of crushing, for example the frequency of postural changes between the birth of the first and the third piglet and the frequency of rollings (postural changes between sternal and lateral recumbency) during farrowing. In a recent study, Andersen *et al* (2005) compared the behaviour of sows that had not crushed any of their piglets and sows that had crushed two of their piglets, and found that the former had a more protective mothering style; responding sooner to piglet distress calls.

Weber (2000) reported that 50-65% of the sows kept in different loose farrowing systems did not crush any of their piglets, and Jarvis *et al* (2005) found that individual sows showed some consistency in piglet mortality over parities, with an estimated repeatability of crushing of 0.14, compared to 0.18 and 0.05 for stillborns and total liveborn mortality, respectively. It might thus be possible to select for sows with low crushing losses (Grandinson 2005). Given that the probability of a piglet dying is strongly related to the length of time it is trapped under the sow (Weary *et al* 1996a), and as there are large individual differences in the responsiveness of sows to piglet distress calls played back when the sow is lying down (Hutson *et al* 1991, 1993), such a behavioural test could be used to select for sows with good maternal behaviour if there were genetic variation in this trait. However, when Grandinson *et al* (2003) recorded the sow's reaction to a piglet scream test carried out on the first day after farrowing in loose farrowing pens, they found a fairly low estimated heritability of 0.06 for this test. Løvendahl *et al* (2005) carried out a similar study with sows housed in farrowing crates, and reported that the estimated heritability of the sows' body response to vocalisation from their piglets when these were handled after farrowing was only 0.08. However, in a further study based on a questionnaire, Vangen *et al* (2005) found considerably higher estimated heritabilities of 0.16 and 0.12 for the sows' reaction to piglets' screaming when handled in Norwegian and Finnish herds, respectively. Finally, calculating estimated heritabilities for different piglet mortality traits, Grandinson *et al* (2002) found a very low estimate for crushing (0.01). Consequently, it would appear that the use of sow behaviour is more promising than the use of crushing rates as a selection criterion to reduce piglet mortality in loose farrowing systems by means of genetic selection.

## Conclusions and animal welfare implications

There is no doubt that housing conditions in farrowing crates are poor in terms of animal welfare, given the results of studies into the normal behaviour of domestic pigs kept in semi-natural environments as well as studies into the behaviour, motivation and stress physiology of sows confined in crates or loose-housed in pens. As a consequence, loose farrowing systems should be favoured. Taking into account the performance achieved in different types of loose farrowing systems and the normal pre-



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parturient behaviour of sows, we conclude that sows should not be group-housed at farrowing, but be kept individually in sufficiently large pens structured for preference into nest and activity areas. With regard to the piglets, it is crucial that all measures are taken to ensure their vitality, not only by providing them with an adequate microclimate and good hygiene, but also by selecting for sows that produce reasonable-sized litters and aiming for low within-litter variability in piglet birthweight. Similarly, sows should be in good physical condition, and it would appear that there are two ways of influencing maternal behaviour to lower the risk of crushing: provision of nest-building material in the preparturient period, and genetic selection for sows reacting well to piglet distress calls. As reviewed here, loose farrowing systems can be as productive as crate systems, not only in experimental studies but also on a large scale and on commercial farms. For individual farmers, the decision to give up crating of sows at farrowing still represents a challenge in terms of housing design and management skills; however, with the information available nowadays, solutions can be found which ensure high productivity in a loose farrowing system.

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