Review on group housing and mixing of sows

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Contents

1. Executive Summary

Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs states that pregnant sows must be housed in groups from four weeks after service until one week before the expected time of farrowing. This review first describes the species-specific social, feeding and exploratory behaviour of sows during pregnancy and their behavioural and physical needs for climate and resting comfort. The change from confinement into group-housing systems for pregnant sows is briefly addressed. By addressing the specific needs, four focus areas relevant for sow welfare, and accordingly relevant for inspections, were identified and highlighted: (1) mixing of unfamiliar pigs, (2) competition for limited resources, (3) restrictive feeding and (4) climate and resting comfort. **Mixing of unfamiliar pigs** leads to agonistic behaviour to establish social relationships; the impact of mixing time, group management and space allowance on welfare aspects such as stress and health is described. Living in groups is associated with **competition for limited resources**, especially for food. The level of aggression related to this competition depends on the way food is delivered. The lack of satiety due to **restrictive feeding** of pregnant sows is a main welfare issue that may lead to "distress" and the development of stereotypies. Finally, it is also important to focus on **climate and resting comfort**, in particular on heat stress in pregnant sows and the importance to lose heat during high ambient temperatures (and humidity). The contraindication of losing heat on floors and the adverse effect of prolonged lying times on hard floors on sow's welfare is also discussed. For each of these focus areas, the review suggests animal-based indicators that inspectors can use to monitor the welfare of group-housed sows. Furthermore, suggestions for improving the welfare situation of group-housed sows are given: minimizing aggression during mixing or in competition for resources, supply of dietary fibre (diets) or roughage to satiate sows, and cooling strategies for group-housed sows, which can be combined with comfortable resting areas. The review concludes with citing the legal requirements relevant to the focus areas.

2. Introduction

The housing of pregnant sows has undergone several changes over the last decades. Before the 1960s pregnant sows were generally kept free in pens, alone or in groups with access to a substantial amount of space, often outdoors during most of the year, e.g. on pasture (Jensen, 1984; D'Eath et al., 2018). The post-war industrialisation of agriculture, aiming to increase production efficiency and output, led to individual confinement becoming the norm. Individual housing of pregnant sows reduces space requirement, labour and management effort. But since then, several studies showed that confinement of sows in a barren environment may cause physical and social stress (e.g. Rushen, 1984; Schouten and Wiepkema, 1991; Geverink et al., 2003). In 1997, the Scientific Veterinary Committee recommended that pigs should not be housed individually because they are social animals except for mature boars and farrowing sows (SVC, 1997). In 2001, European Council Directive 2001/88/EC laying down minimum standards for the protection of pigs emphasized that sows and gilts shall be kept in groups (EC, 2001).

Since 2013, member states of the EU have to ensure that sows and gilts are kept in groups during a period starting from four weeks after service to one week before the expected time of farrowing (see Council Directive 2008/120/EC, Article 3, Point 4.). Whereas in the 90'ties some EU member states already

practised group-housing, most member states converted very slowly. Nowadays, a wide variety of group housing systems exists, and differences mainly relate to housing (e.g. space allowance, floor or feeding system), group management, time of mixing, and stockmanship (reviewed by Spoolder et al., 2009; Verdon et al., 2015; Maes et al., 2016).

However, group-housing in itself does not guarantee welfare of sows, and a blueprint for an ideal group-housing system does not exist. In conventional housing sows are often mixed with unfamiliar sows, which provokes high levels of aggression and adversely affects sow welfare (Verdon et al., 2015). Furthermore, most group-housing systems only provide limited access to resources, which provokes prolonged levels of aggression due to competitive behaviour for resources. Therefore, Council Directive 2008/120/EC additionally requires provision of bulky or high-fibre feed and materials to explore (Damm, 2008) to minimize aggression and food competition.

Sow welfare during pregnancy may succeed when group-housing facilities and management practices consider more the behavioural and physiological needs of sows and do not force them to cope with stressful housing environments. Thus, this review provides knowledge on sow behaviour and their cohabitation in social relationships. It further highlights four focus areas for welfare in sows kept in groups under commercial conditions: (1) mixing with unfamiliar pigs, (2) competition for resources, (3) restrictive feeding and (4) climate and resting comfort. Additionally, the review provides specific animal-based indicators, which may help inspectors to identify welfare issues of group-housed sows. Finally, the review provides scientific knowledge on improved practices for each of the four focus areas considering behavioural and physiological needs of sows to enhance their welfare when group-housed, and deals with related legislative requirements.

3. Scientific knowledge on the behaviour and physiology of sows

In nature, sows live in small maternal groups of two to four sows with their offspring and juveniles (Mauget, 1981; Graves, 1984). The animals of a group are closely related females and unfamiliar sows are rarely allowed to incorporate into a group (Stolba and Wood-Gush, 1989; Gonyou, 2001). A new social group is possibly formed if a sow and her female juveniles leave, or if several female offspring disperse together without an adult (Gonyou, 2001).
Within each social group long-time social relationships exist (Mauget, 1981), and most often mature sows are dominant over sub-adults and juveniles (Mauget, 1981; Marchant-Forde, 2009). The social relationships are maintained by subordinate animals avoiding physically strong animals, rather than dominant sows attacking those of lower status (Jensen, 1980;1982). Within a social group, aggression is rare, but may occur during competition for resources such as for food (Jensen and Wood-Gush, 1984; Marchant-Forde, 2009). During the mating season, the social group is joined by a boar, who assumes dominance above all members of the group, while the relationships between females and juveniles remain unchanged (Fradrich, 1974; Graves, 1984; Gonyou, 2001).

Each social group has its own home range, which may overlap or is in close proximity to other social groups, especially during seasons of heavily concentrated food resources. However, groups do not

interact and tend to actively avoid open confrontation (Gabor et al., 1999; Gonyou, 2001; Marchant-Forde, 2009). Sows have a diurnal activity pattern. In semi-natural environments they spent 75 % of their daytime activity with foraging-related activities, including rooting, grazing and exploring substrates with their snout (Stolba and Wood-Gush, 1989). Group members forage mostly together with an average distance of nearly 4 m from their nearest neighbour (Stolba and Wood-Gush, 1989; Marchant-Forde, 2009). Pigs are monogastric animals and can digest fibrous plant materials or extract energy from cellulose less efficient in comparison to ruminants. Only older pigs can extract considerable energy from non-starch fibre sources by fermentation and have a significant potential for dietary fibre utilisation (Marchant-Forde, 2009).

Around midday and at night sows and their offspring will rest together in a communal nest, except during the farrowing season (Stolba and Wood-Gush, 1989; Gonyou, 2001). Domestic pigs kept outdoors choose dry lying areas and avoid draughty ones. They cushion their lying area with bedding material such as straw if available. (Gunnarsson, 2018). A comfortable sleeping area provides shelter, promotes calmness and allows comfortable lying in a lateral position. However, lying laterally may also depend on the ambient temperature. Sows are homeothermic animals with a thermoneutral zone between 15 and 20 °C (Black et al., 1993). At temperatures above the upper limit of their thermoneutral zone sows show evidence of heat stress, reduced activity, delayed return to oestrus and lying laterally (Bracke, 2011; Serviento et al., 2019). Under semi-natural environments pigs regularly wallow if the upper limit of their thermoneutral zone is reached (Stolba and Wood-Gush, 1989). Bracke (2011) reviewed that pigs are positively motivated to wallow in mud or water to loose heat by evaporation. In case pigs do not have access to a proper mud pool they will seek for wet surfaces and may lie in their own faeces or urine.

4. Key areas to focus on during welfare inspections and assessing animal welfare indicators

Based on the knowledge of sow physiology and behaviour, four focus areas are identified to focus on during welfare inspections of group-housed sows during pregnancy.

- **Mixing of unfamiliar animals**
- **Competition for resources**
- **Restrictive feeding**
- **Climate and resting comfort**

Animal-based indicators help to identify inadequate conditions within these key focus areas and can be used in animal welfare inspections to quantify sows' welfare status in certain group-housing systems. In the following paragraphs, relevant animal welfare indicators are printed in bold when first described.

4.1 Mixing of unfamiliar animals

Group-housed sows are mixed at least once in each reproduction cycle with unfamiliar sows (Edwards, 1992). Mixing occurs when sows move from the farrowing to the service unit. Due to individual housing during farrowing, they are physically separated from their herd-mates until weaning and selected for a

new group by the farmer at weaning. Although the composition of the group may be very similar to the previous cycle, new sows may join a group at weaning, e.g. because of failed insemination at prior oestrus or pregnancy (Marchant-Forde, 2009).

Groups of sows are managed either as static or dynamic groups. In static groups unfamiliar sows are mixed only once per gestation. In dynamic groups resident sows experience several mixings per gestation because new sows will frequently be introduced to an existing group (Marchant-Forde, 2009). With each change of group composition sows have to re-establish their social relationships (Meese and Ewbank, 1973; Ringgenberg et al., 2012). Aggression at mixing is mostly limited to the first 24-48 h after mixing (Marchant-Forde, 2009). Once the social hierarchy is established, aggressive behaviour can be kept to a minimum in group-housing systems if they are well managed and designed (Bos et al., 2016).

However, mixing always leads to social stress and provokes agonistic behaviour to establish a social hierarchy. Aggression which occurs to establish social relationships is less frequent but can be far more intensive in comparison to aggression shown when sows compete for limited resources (Spoolder et al., 2009). Fights resulting from mixing of unfamiliar pigs can last for several minutes (Mount and Seabrook, 1993). When pigs fight, they attempt to target head, neck and ears of the opponent. Fighting additionally includes parallel or parallel inverse pressing, chasing and forcing another pig to leave and avoid certain places. Furthermore, pigs use their canine teeth to bite and strike at their opponent. This results in the accumulation of **skin lesions** predominantly at the front third of the body, but also at the flanks when delivered in a reverse parallel posture (Turner et al., 2006).

Aggressive interactions amongst sows may result in slipping and falling on (slippery) floors, in particular when sows are kept on a fully slatted floor. Slipping and falling may increase the risk of claw and leg lesions. According to Pluym et al. (2017), claw and leg lesions in sows may cause **lameness.** However, their data failed to confirm an association between mixing of unfamiliar sows and lameness (Pluym et al., 2017). In contrast, a link between aggressive interactions and lameness was demonstrated by Heinonen et al. (2013), who observed lameness mainly shortly after introduction of sows into groups. Lameness affects sow welfare because it is painful, lame sows are not able to move normally, and they may not be fit enough to compete with healthy-legged sows for food and water. They may thus also suffer from hunger and thirst (Madec et al., 1986).

It is important to note that insufficient space allowance at mixing increases the risk of adverse consequences of aggressive behaviours, e.g. shown by increased skin lesions (reviewed by Spoolder et al., 2009; Verdon et al., 2015). Insufficient space reduces the opportunities of subordinate sows to avoid aggression and flee from dominant ones. This additionally leads to higher levels of stress for receivers of aggressive encounters (Spoolder et al., 2009).

Reproductive sows are normally mixed either directly after weaning, after insemination, or after pregnancy detection (Verdon et al., 2015). Verdon et al. (2015) reviewed that the stage of the reproductive cycle at which sows are mixed may affect aggression. For instance, Stevens et al. (2015) observed that sows mixed in the week after insemination were more aggressive in comparison to those

mixed five to six weeks after insemination. Other studies found no differences of aggression levels following mixing between early and late pregnancy (Strawford et al., 2008; Knox et al., 2014). Thus, results seems to be contradicting but other factors such as the type of group-housing system and individual characteristics of sows may be influential (Spoolder et al., 2009). Sows generally ovulate 15-30 oocytes in one oestrous period and embryos implant to the uterine wall around day 11-16 after insemination (Soede et al., 2011). Shortly thereafter the so-called "maternal recognition of pregnancy" begins (Verdon et al., 2015). Stress may negatively affect litter size due to embryo mortality around that period and should be avoided especially in weeks 2-4 of pregnancy (Spoolder et al. 2009). Thus, mixing at weaning or mixing in the first week after insemination is preferred in practice.

4.2 Competition for resources

When pigs live in groups, they compete for limited resources, especially for food. When food is widely available in a sufficient quantity, competition is low, whereas competition is high, when food is scarce or if a resource is easy to defend by one animal. Pigs have various behavioural strategies to gain access to food. They can show offensive behaviour including fights, e.g. in forcing an animal to leave a food resource, but they also can show defensive behaviour including a delay in entering or retreating from a conflict for a food resource (Boumans et al., 2018). Due to agonistic behaviour and fights **skin lesions** may occur (Turner et al., 2006). Aggression related to competition for resources tend to continue even after stable social relationships have been established. Aggressive interactions resulting from competition generally are very short in duration but very frequent (Spoolder et al., 2009).

The level of aggression related to competition for food depends on the type of feeding system (Spoolder et al., 2009). Within group systems, sows may be fed collectively (either on the floor or in troughs) or individually (in feeding stalls or electronic sow feeders (ESF)) (Bench et al., 2013a). In floor feeding systems, food is either manually or automatically delivered directly on the pen floor (Verdon et al., 2015). However, floor feeding is very competitive, because subordinate sows do not have any protection from dominant sows while eating and may thus be forced to retreat from eating. Verdon et al. (2015) reviewed studies which report a large variation of food intake of sows in floor feeding systems. Especially younger sows are not able to consume their ration as quickly as older sows, whereas dominant sows defend their access to food and eat as much as they can. Thus, under- and overfeeding may negatively affect sows' **body condition** (Spoolder et al., 2009). In trough feeding systems similar high levels of aggression and negative effects on sows' body condition may be observed. Especially dominant sows monopolize large parts of the trough, displacing subordinate sows and consume large amounts of energy rich food in a short time, especially if food distribution along the trough is uneven (reviewed by Marchant-Forde, 2009).

The most common feeding system for group-housed sows are individual feeding stalls in which sows can be confined whilst feeding, for example, by self-locking doors. The major advantage of this system is that sows can eat simultaneously and be fed individually while protected from each other (Marchant-Forde, 2009). This ensures optimal body condition of each sow during pregnancy (Edwards, 1985). Although feeding in stalls reduces aggression and competition is lower compared to floor feeding (Barnett et al., 1992), aggression and competition may occur also in feeding stalls if sows can enter other sows stalls after

finishing their own ration (Bench et al., 2013b; Verdon and Rault, 2018). This may be indicated by **vulva lesions** due to biting in feeding stalls, where sows are not enclosed during feeding time (Andersen et al., 1999).

A second individual feeding system is the Electronic Sow Feeder (ESF) system. This system allows the greatest possible control over individual sow intake, but forces sows to feed in sequence. Usually a feeding order develops within a group of sows, which is closely related to the dominance relationship, in that the dominant sows will generally start to eat within a new 24 h cycle (reviewed by Spoolder et al., 2009). A single feeder is usually expected to be used by 40-60 sows. Thus, the ESF system is normally used for large dynamic groups. The consequence of sequential feeding is that the entrance to the feeder can become a focus of activity for large parts of the day, and where there is activity combined with limited access to a resource, there are likely to be aggressive interactions (Marchant-Forde, 2009). Verdon et al. (2015) reviewed that queuing at the entrance of the feeder provokes aggression including vulva biting, when sows try to obtain access to the feeding station.

However, aggression in group-housed sows may not only be influenced by the given feeding system, but can also be affected by the amount of the space (Marchant-Forde, 2009). Space allowance has a large impact on sow behaviour, including agonistic social behaviour with possibly adverse effects on sow welfare (Verdon et al., 2015). According to Spoolder et al. (2009) the minimum space allowance necessary for sows in group housing systems remains scientifically undefined. In general, three types of space are required to meet the behavioural needs of the pigs: (1) static space, (2) behavioural space and (3) interaction space. A certain static space is required for standing or lying, and can be calculated by the formula as proposed by Ekkel et al. (2003). A formula on the behavioural space required for behaviours such as feeding or dunging is lacking for sows. Further, Spoolder et al. (2009) states that interaction space is defined by activities such as mating, fighting and fleeing. It may be estimated, although with some difficulty, with a formula from Baxter et al. (1985). Although sows may adapt to reduced space once the social relationships are established (Hemsworth et al., 2013), there exists scientific evidence that with decreased space allowance the total number of aggressive interactions per sow increases (reviewed by Marchant-Forde, 2009).

However, it should be noted that space may interact with other pen design features, such as location of key resources and the presence of visual and physical barriers (Verdon et al., 2015). Especially competition for access to other resources such as the drinker (Chapinal et al., 2010), foraging material (Bench et al., 2013b) and preferred lying areas (Strawford et al., 2008) may have an impact on agonistic behaviour in group-housed sows (reviewed by Verdon and Rault, 2018). For instance, the location where sows rest within the pen may be related to social dominance (Strawford et al., 2008). Older dominant sows often monopolize preferred resting areas, forcing the younger, subordinates ones, to lie in the less preferred areas of the pen, for example in dunging areas (Hodgkiss et al., 1998; O'Connell et al., 2003). Thus, **manure on the body** may indicate that sows compete for preferred lying areas and that the behavioural needs of low-ranked sows in the group are not met.

4.3 Restrictive feeding

Pregnant sows are commonly fed restricted to prevent excess of body weight gain and fat deposition, which can cause farrowing and locomotion problems and subsequently reduce reproductive performance (Meunier-Salaün et al., 2001). Thus, pregnant sows are typically fed their entire ration once a day or in two meals (D'Eath et al., 2018). The diet usually offered in commercial systems is rapidly consumed and does not keep the sows satiated for more than 1 or 2 h (Danielsen and Vestergaard, 2001; Meunier-Salaün et al., 2001). D'Eath et al. (2018) reviewed studies in which pregnant sows were required to work for having access to additional food. From these studies, it is evident that restrictive fed sows remain highly feed-motivated. Sows showing increased activity and foraging-related oral behaviour, or attempts to access additional food indicate that they are likely to suffer from hunger throughout a large part of the day (Marchant-Forde, 2009).

D'Eath et al. (2018) suggests several internal and external factors which may influence an animal's level of feeding motivation, expressed by food-searching behaviour (e.g. foraging, approaching the feeder) before the food is eaten. In the absence of natural foraging opportunities, sows often show redirected oral behaviours, known as **stereotypies**. These behavioural patterns will be performed repetitively in a fixed order and without any apparent function. Examples are sham chewing, biting, nosing and licking of technical equipment or excessive manipulation of drinkers (Fraser, 1975; Rushen, 1985; Terlouw et al., 1991; D'Eath et al., 2018). Stereotypies are mostly shown immediately after feeding. They are interpreted as an indicator for impaired welfare and are generally considered to be a sign of stress or frustration (Wiepkema et al., 1983; Meunier-Salaün et al., 2001).

Satiety can be increased by increasing the level of dietary fibre and increasing the amount of food by lowering the energy concentration in the diet (reviewed in Marchant-Forde, (2009)). Pigs can digest some fibre by fermentation with their commensal hindgut microflora, and especially sows have a high capacity to digest fibrous diets (reviewed by D'Eath et al., 2018). However, de Leeuw et al. (2008) hypothesized that the beneficial effects of dietary fibre on sow hunger and feeding motivation may depend on the specific characteristics of the fibre used rather than on total fibre intake. Fibre can be divided into insoluble, soluble and highly fermentable fibre with different impacts on sows' digestion (Verdon et al., 2015). Jensen et al. (2012) found no reduction of feeding motivation irrespective of fibre source in comparison to a control diet (18 % dietary fibre). They fed three different fibre sources (35% dietary fibres) once or twice daily. Other studies have shown that high dietary fibre content in pregnant sows increases eating times and can contribute beneficially to satiety both pre-meal, during meal, post-meal and several hours after meal. The increased satiety reduces stereotypies and general activity, and increases resting. However, when comparing diets that differ in fibre content, it is important to accurately know the energy value of diets, so that feed quantity can be adjusted to provide an equivalent energy intake, thereby allowing a fair comparison of the effect of fibre (reviewed by D'Eath et al., 2018).

4.4 Climatic and resting comfort

Sows have a very limited number of sweat glands, and therefore a limited capacity to lose heat by evaporation from the skin. Thus, sows thermoregulate mostly via behavioural adaptations when ambient

temperatures fall below or above 15-20 °C, i.e. their thermoneutral zone (Black et al., 1993). Sows begin to show signs of heat stress at a temperature of 20°C, and temperatures of 26°C and higher are considered as critical for pigs (Christianson et al., 1982; Quiniou et al., 2001).

Heat stress, e.g. during high ambient temperatures and high relative humidity levels (60-90 %), reduces food intake followed by a loss of body condition, and provokes reproductive problems in sows (reviewed by Lucy and Safranski, 2017). In early pregnancy, heat stress increases embryo mortality, which affects farrowing rate and litter size (Nardone et al., 2006), whereas heat stress during late pregnancy increases the number of stillborn piglets (Lucy et al., 2012), and reduces newborn piglet weight (Edwards et al., 1968; Omtvedt et al., 1971; Lucy et al., 2012; Wegner et al., 2016). Behavioural adaptations under warm and humid conditions are **panting** or lying in water puddles, mud, or own excreta, which may cause poor body hygiene due to **manure on the body** (Ingram, 1965; Aarnink et al., 1996; Huynh et al., 2005; Pang et al., 2011). Furthermore, under warm conditions, group-housed sows may seek cooler floor surfaces, for example slatted floors, to lose body heat on the floor surface and, thus, increase lying durations (Lucy and Safranski, 2017). If space is limited, this results in competition for lying space on the slatted floor that may lead to aggression and skin lesions.

Sows spend approximately 80 % of their time lying (Buckner et al., 1998). Regarding comfort around resting sows may benefit from concrete floors to lose heat when ambient temperatures are high. However, because of their hard surface, lying on concrete floors may cause discomfort during prolonged lying times. This may lead to pressure injuries on the hind limbs, like bursitis and capped hock (von Berner et al., 1990; Maes et al., 2016). Especially in sows, calli, bursae and capped hocks may lead to an abnormal gait (von Berner et al., 1990; Bonde et al., 2004; KilBride et al., 2009). According to KilBride et al. (2009) limb lesions are often associated with abnormal gait and directly or indirectly cause the pigs to be less comfortable during lying which in turn increase the risk of **lameness.** On the other hand, limb lesions and lameness are associated because lame pigs spent more time lying in order to avoid standing and walking. Lameness indicates that a pig is experiencing pain and discomfort (Fraser et al., 1997; KilBride et al., 2009; Heinonen et al., 2013).

5. Minimising welfare problems: improved practices

5.1 Improving mixing of unfamiliar animals

In commercial group-housing systems, mixing unfamiliar sows at least once per reproduction cycle seems unavoidable. The aim should be to (re)mix sows with sows of the same group they previously belonged to. Pigs have a good memory and will recognise their former group members. Another good practice is to (temporarily) increase space allowance at mixing. However, space needed for fighting and fleeing is often difficult to estimate. Baxter (1985) estimated the amount of space two sows need when engaged in a two sided fight to be $0.11 * W^{0.667}$ where W is the current body weight of the pigs (reviewed by Spoolder et al., 2009). For two average sized pregnant sows with a bodyweight of 240 kg the formula would result in a space required for agonistic interactions of 4.2 m². Council Directive 2008/120/EC requires 2.25 m² space per sow. Thus, standard group-housing systems may not provide sufficient space at the time of

mixing. Consequently, several authors suggest to use particular mixing pens (reviewed by Verdon et al., 2015) in which sows should be kept for the first 2-3 days after mixing. These pens should allow the sows to achieve a flight distance of 10-12 m (Spoolder et al., 2009). Additionally, mixing pens should include straw or rice hulls as bedding providing both rooting material and a good grip for the claws while fighting or fleeing (Verdon et al., 2015). Although bedding does not reduce aggression, it will reduce the risk of leg problems, which may reduce the occurrence of lame sows due to mixing (Spoolder et al. 2009). Verdon et al. (2015) found only limited evidence for possible effects of the layout of mixing pens that can be rectangular, square or round. Visual barriers within the pens seem to support sows avoiding fights as they can hide from dominant sows (Spoolder et al., 2009; Verdon et al., 2015). Edwards et al. (1993) reported that such barriers reduced total aggression by nearly 30 % in the 12 h after mixing.

An example of a mixing pen built by using a large tent (© LSZ Boxberg)

The presence of very aggressive sows can extend the time for establishing social relationships (Tönepöhl et al., 2013). Because there is a genetic disposition for aggressive traits in sows, selection against sow aggression appears to be feasible (Verdon et al., (2015).

5.2 Reducing competition for resources

Competition for resources such as for food can be very low if a sufficient amount of food is available to all sows of a group and high if access to food is restricted or food sources are easily defended by dominant sows (Boumans et al., 2018). If pigs are restrictively fed with energy rich diets, which is common in pregnant sows, competitive behaviour will arise. However, it should be avoided that dominant sows are rewarded with extra food by chasing away subordinate sows (Spoolder et al., 2009). Therefore, lockable feeding stalls allowing sows to eat simultaneously and protecting subordinate sows from food stealing by dominant ones are recommended (Andersen et al., 1999). In floor feeding systems aggression can be

lowered if food is spread widely on the feeding area allowing all sows access to food simultaneously (Gonyou, 2005).

In Electronic Sow Feeder (ESF) systems the design of the pen and the placement of the ESF affect aggression. The position of the ESF should be away from busy areas and other resources (e.g. drinkers, enrichment materials, racks). Furthermore, a long distance from exit to entry of the ESF and sufficient space around the ESF station (Bench et al., 2013b) may help to reduce aggression and to enhance accessibility of the ESF for subordinate sows (Verdon et al., 2015). Additionally, non-slippery floors can reduce injuries of legs and claws (Bench et al., 2013b). Furthermore, repeated non-feeding visits of dominant sows should be prevented (i.e. visits after they have eaten their allocated daily ration), because dominant sows may occupy the ESF to the detriment of subordinate sows. This can be achieved by installing a computer controlled gate at the entry of the feeder which only allows access to sows that have not yet received their daily ration.

Innovative feeding systems should be considered for group-housed sows, for instance, a call feeding station. This allows sows to enter a feeding station only after being called by an individual acoustic signal, which can reduce agonistic interactions in front of the feeding station (Kirchner et al., 2012).

Finally, competition for food can be reduced by additional provision of roughage (Gjein and Larssen, 1995). However, roughage should be offered *ad libitum* and all sows should have access to the racks with roughage in order to prevent that roughage becomes an additional limited resource for which sows will compete.

Lying areas also may become a limited resource for which sows compete. Thus, sufficient lying space should be available. The lying area should be separated from activity and dunging areas. From the sows' point of view, lying area should provide shelter, but also a good view on the surroundings. Lying areas can be established with a solid floor and a slight slope to get rid of urine. They can be equipped with closed side walls to protect lying sows from being disturbed by other sows. Lying areas should provide enough space such that all animals can lie at the same time. Considering the different lying positions of sows, at least at higher temperatures lying space should allow sows to lie in a fully lateral position simultaneously. According to Ekkel (2003) sows of 240 kg body weight will need an area of on average 1.7 m² per sow for lying in a lateral position.

5.3 Measures to increase satiety in restrictively fed sows

Fibrous materials can be provided by including high levels of fibrous ingredients in the diet, allowing a larger volume of food without increasing the energy and nutrient ingredients. Alternatively, fibrous materials can be offered separately in racks or on the floor (Meunier-Salaün et al., 2001). Fibrous materials that have been studied as ingredients in diets for pregnant sows are mainly wheat bran, sugar beet pulp, soybean hulls, oat hulls and potato pulp (reviewed by D'Eath et al., 2018). Fibre ingredients were supplemented from 9 to 65 % per kg dry matter of the diet. Stewart et al. (2008) investigated the impact of dietary fibre on the level of stereotypies and showed that an amount of 9 % fibre in the diet could

decrease stereotypies only if straw is also provided. Jensen et al. (2012) investigated diets with 35 % dietary fibres of different origin and found only a limited impact on satiety as measured by the sows' motivation to work for additional food. Thus, additional *ad libitum* access to roughage in combination with a low fiber diet seems the most effective way to increase satiety in restrictively fed sows (Verdon et al., 2015).

Ad libitum provision of hay, pressed in round bales (© LSZ Boxberg)

Werner et al. (2014) studied the effect of an *ad libitum* supply of five different roughage components in combination with a restrictive supply of a basal diet to pregnant sows, on sow and piglet health after birth. They reported that clover grass silage and maize silage were the most eaten roughage components by pregnant sows with up to 1.6 and 2.3 kg DM per day in early pregnancy and up to 1.3 and 1.5 kg DM per day in late pregnancy. Up to 25 % of silage could be included in the diet without having a negative impact on the sows' performance. Thus, silage that is tastier compared to straw should be considered in diets for pregnant sows in order to increase satiety. Another innovative strategy to feed roughage for pigs may be offering a total-mixed-ratio (TMR) as in cattle (Kim et al., 2013; Presto Åkerfeldt et al., 2018).

Roughage, provided as feedstuff, should always be offered in racks or (automatically) in troughs. A suitable rack for pregnant sows has a feeding height of 40-45 cm and the distance between bars (axial dimension) should be 11-13 cm (Baumgartner et al., 2011) in order to allow access to the roughage. Racks can be placed in the outdoor run if available. Racks should be placed in a position allowing access for all sows and, thus, avoiding that roughage becomes a limited resource. Straw bedding has also been suggested to reduce stereotypic behaviour in pregnant sows (Spoolder et al., 1995; Whittaker et al., 1998; Whittaker et al., 1999).

5.4 Improving climatic and resting comfort

In group-housing systems, sows most often have access to slatted floors on which they will lie at high temperatures for thermoregulation. However, prolonged lying on hard floors can negatively affect their welfare by increasing the risk for lesions at the shoulders and legs. Thus, pregnant sows should be provided with adequate resources and an environment allowing proper heat dissipation. Two cooling methods are mainly applied in practice (Barbari and Conti, (2009): Cooling by water evaporation acting on the environment and by showering acting directly on the animal. In regions with hot-dry climates, evaporative cooling or fogging is preferred in order to limit the adverse effects on indoor humidity. However, attention must be paid to the accurate control of fogging and ventilation (Haeussermann et al., 2007). For example, evaporative cooling systems decrease the ambient temperature by 5-7 ° inside pig barns, depending on the outside temperature and relative humidity (Lucy and Safranski, 2017). In wet-hot regions, direct water sprinkling of sows by showers generally is more effective in comparison to evaporation of water into the air (Nichols et al., 1982). Showers are often controlled by a timer, which starts water sprinkling at certain time intervals. A disadvantage of shower cooling is the heavy water use and the collection of high amounts of water in the slurry with negative effects on slurry dilution (Barbari and Conti, 2009).

Comfortable lying areas have a soft floor but should also provide sufficient grip (Webb and Nilsson, 1983). To enhance resting comfort bedded lying areas are recommended. Sows kept on straw or deep litter bedding have a lower risk for claw lesions and lameness than sows kept on solid concrete or slatted floors (reviewed by Spoolder et al., 2009). When straw bedding is used, however, hygiene is important. Damp straw, soiled with faeces and urine, can soften the claws, which makes them more prone to abrasion and pressure-induced lesions, thereby increasing the risk of claw infections and lameness (Whittaker et al., 1999). Thus, straw can be recommended as bedding material in the lying area, but it should be of good quality.

In commercial housing facilities with slatted floors straw bedding is difficult because it is hardly compatible with liquid manure systems. In case straw bedding is not possible, rubber mats are a suitable alternative to offer a comfortable lying area for gestating sows (Tuyttens et al., 2008; Elmore et al., 2010; Calderon Diaz et al., 2013). On rubber mats the prevalence of limb lesions and the risk for lameness can be reduced (Calderon Diaz et al., (2013). In addition, lying times and frequency of lying in half-recumbent compared to sternal position increase (Tuyttens et al., 2008; Elmore et al., 2010). When given the choice, pregnant sows prefer soft, followed by hard rubber mats for lying in comparison to a concrete floor (Baumann et al., 2013). In addition, in that study sows were lying less often in a lateral position on the concrete floor compared to rubber mats.

Sows lying in lateral position on rubber mats (©LSZ Boxberg, S. Baumann)

Schubbert et al. (2014) measured pressure load on different body parts of pregnant sows while lying on rubber mats with different levels of softness, and on concrete. Compared with a concrete floor, only a very soft rubber mat with a penetration depth of 43 mm significantly reduced the peak force on the sternum while lying in a sternal position and on the shoulder while lying in a half-recumbent position. Thus, only soft rubber mats improve lying comfort.

In addition to straw and rubber mats, natural substrates (e.g. peat, mushroom compost) may be attractive for sows as lying surfaces (Bench et al., 2013b). Such substrates may even better reduce the risk for lameness and may be better compatible to manure systems. However, there is a lack of studies on the use of these substrates in group-housing systems for sows (Maes et al., (2016).

6. Legal requirements

In this chapter, extracts from **Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs** are listed that are relevant with regard to the four focus areas for inspecting the welfare of group-housed sows.

6.1 Legal requirements applying to mixing of unfamiliar animals

Council Directive 2008/120/EC states in Article 3(4) that *"Member states shall ensure that sows and gilts are kept in groups during a period starting from four weeks after the service to one week before the expected time of farrowing."* Whereas, *"By way of derogation from the first subparagraph, sows and gilts raised on holdings with fewer than 10 sows may be kept individually during the period mentioned in that subparagraph, provided that they can turn around easily in their boxes."*

To minimize aggression in groups of pigs, Council Directive 2008/120/EC states in Annex I, Chapter II, Point B (1) that *"Measures shall be taken to minimise aggression in groups."* Furthermore, *"Member States shall ensure that pigs that have to be kept in groups, that are particularly aggressive, that have been attacked by other pigs or that are sick or injured may temporarily be kept in individual pens. In this case the individual pen used shall allow the animal to turn around easily if this is not in contradiction with specific veterinary advice."* {Article 3(8)}.

Concerning space allowance Council Directive 2008/120/EC states for gilts and sows that *"the total unobstructed floor area available to each gilt after service and to each sow when gilts and/or sows are kept in groups must be at least 1.64m² and 2.25 m² respectively. When these animals are kept in groups of fewer than six individuals the unobstructed floor area must be increased by 10 %. When these animals are kept in groups of 40 or more individuals the unobstructed floor area may be decreased by 10 %."* Article 3 (1b). Furthermore: *"The pen where the group is kept must have sides greater than 2.8 m in length. When fewer than six individuals are kept in a group the pen where the group is kept must have sides greater than 2.4m in length.* {Article 3(4)}.

6.2 Legal requirements applying to competition for resources

"All pigs must be fed at least once a day. Where pigs are fed in groups and not ad libitum or by an automatic system feeding the animals individually, each pig must have access to the food at the same time as the others in the group." Annex I, Chapter I, Point 6. In addition, Council Directive 2008/120/EC states that *"Member states shall ensure that sows and gilts kept in groups are fed using a system which ensures that each individual can obtain sufficient food even when competitors for the food are present."* {Article 3(6)}.

According to Council Directive 2008/120/EC *"all pigs over two weeks of age must have permanent access to a sufficient quantity of fresh water."* {Annex I, Chapter 1, Point 7}.

6.3 Legal requirements applying to restrictive feeding

Council Directive 2008/120/EC states in Article 3(7) that *"Member states shall ensure that all dry pregnant sows and gilts, in order to satisfy their hunger and given the need to chew, are given a sufficient quantity of bulky or high-fibre food as well as high-energy food".*

Furthermore, *"Member states shall ensure that, without prejudice to the requirements laid down in Annex I, sows and gilts have permanent access to manipulative material at least complying with the relevant requirements of that Annex."* {Article 3(5)}. In Annex I, Chapter I, Point 4 is stated that "*Notwithstanding Article 3(5), pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals.*"

6.4 Legal requirements applying to climatic and resting comfort

Council Directive 2008/120/EC states that pigs must "*have access to a lying area physically and thermally comfortable as well as adequately drained and clean which allows all the animals to lie at the same time, rest and get up normally*." {Annex I, Chapter I, Point 3}.

Furthermore the Council Directive 2008/120/EC states that at least 1.3m² per sow must be of continuous solid floor of which a maximum of 15 5 is reserved for drainage openings.

Additionally, according to Annex I, Chapter I, Point 5 "*Floors must be smooth but not slippery so as to prevent injury to the pigs and so designed, constructed and maintained as not to cause injury or suffering to pigs. They must be suitable for the size and weight of the pigs, and if no litter is provided, form a rigid, even and stable surface*."

Furthermore, it is generally described in the Annex (Point 10) of the **Council Directive 98/58/EC**, that in buildings "*Air circulation, dust levels, temperature, relative air humidity and gas concentrations must be kept within limits which are not harmful to the animals*.

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7. References and review papers for further reading

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