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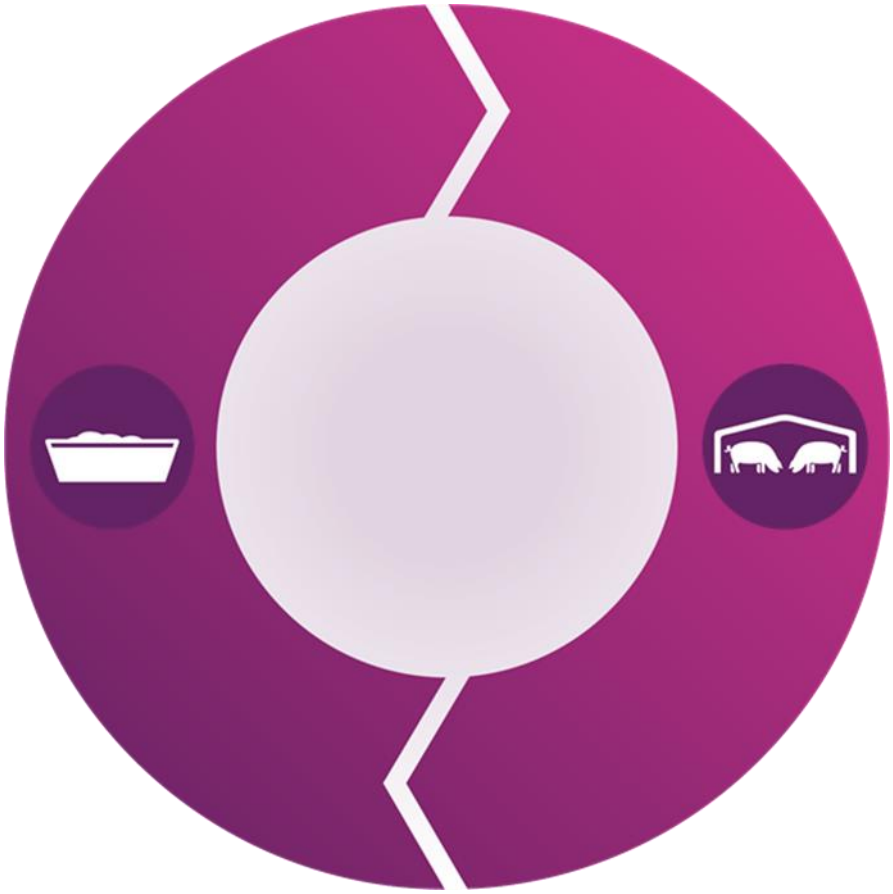

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Review on hunger induced behaviours: aggression and stereotypies

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July 2022

This review is a publication of the European Union Reference Centre for Animal Welfare Pigs (EURCAW-Pigs). EURCAW-Pigs was designated by the European Union on 5 March 2018 through Regulation (EU) 2018/329, in accordance with Articles 95 and 96 of Regulation (EU) 2017/625.

Each EURCAW-Pigs review provides background information on the biological relevance of the welfare topic. It then presents the most important key areas to focus on during welfare inspections, describes why welfare issues occur and lists specific animal-based indicators that can help official inspectors to identify these welfare issues. Finally, the review summarizes ways of good and better practices that can help to solve the previously described welfare issues, and deals with related legislative requirements.

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Co-funded by the European Union

Contents

1 Executive Summary

According to Council Directive 98/58/EC (1998) animals must be fed a diet that is appropriate to fulfil their physiological needs. However, pregnant sows are generally fed at a restricted level to avoid a high body condition score and the risk of farrowing problems. Restrictive feeding has welfare implications as it may lead to hunger, stereotypic behaviour and increased aggression.

When feed is available *ad libitum* competition is low, whereas competition is high when food is scarce or if access to the resource is easy for one animal to control. Competition often leads to aggressive behaviour and this may result in stress to both the aggressor and the receiver. Additionally, aggressive behaviour can result in lesions or lameness that can cause pain. Inspectors can measure aggression directly, by observing behaviour, and indirectly, by counting the resulting skin lesions.

Similarly, stereotypies relate to feed restriction and are likely to reflect the inability of the sow to fulfil her motivation to eat until she is satiated. When sows cannot respond to hunger in a species-specific way, they may develop oral stereotypies. Depending on the possibilities to interact with the housing environment, this motivation can result in the expression of different types of stereotypies. The presence of animals with stereotypic behaviour can be seen as a sign of stress that might also affect animals that do not show the behaviour. Observations can be performed using so called 'ethograms', describing the different types of stereotypies.

There are several ways to reduce the welfare issues resulting from feed restriction. They divide into solutions that help to reduce the underlying problem of hunger and those that mitigate the resulting aggression and stereotypies. To reduce the root cause of the problem, sows need to feel more satiated during gestation which can be achieved by e.g. changing the type of feed offered to the animals, for example through greater inclusion of dietary fibre. Solutions to mitigate aggression and stereotypies resulting from feed restriction or limited access to feed relate to aspects of housing such as space, flooring, substrates, feeding system, and complexity of the environment.

This review aims to support inspectors of EU member states in understanding the science and regulations related to pig welfare concerning hunger induced aggression and stereotypies. Underlying mechanisms and causes of these behaviours in sows related to hunger are described. Furthermore, measures to reduce welfare risks related to aggression and stereotypies are discussed followed by ways for inspectors to measure these behaviours.

2 Introduction

Pregnant sows are generally fed at a restricted level to avoid overweight/high body condition score and the risk of problems at farrowing. However, restrictive feeding has welfare implications as it may lead to hunger, stereotypic behaviour and increased aggression.

This review looks at the causes of and ways to reduce these risks to animal welfare.

3 Scientific knowledge on nutritional needs of sows

3.1 Nutritional needs of sows

Gestating sows are fed to maintain a body condition (Dourmad, Etienne, Prunier, & Noblet, 1994) for health and optimal performance in each stage of the reproductive cycle. They are provided with 2–3 kg of concentrate feed daily in one (or sometimes two) meal that is rapidly consumed in around 20 min. The diets are formulated to meet the sow's nutritional needs as well as that of her growing unborn piglets, with adjustments based on factors including parity, body condition and stage of pregnancy (Ball, Samuel, & Moehn, 2008). When fed a conventional diet *ad libitum*, a sows intake of feed will be greater than the amount needed to maintain body condition (Meunier-Salaün, Edwards, & Robert, 2001). Petherick and Blackshaw (1989) found that sows fed *ad libitum* with a concentrated diet eat about three times the amount they would need to maintain body condition. Brouns, Edwards, and English (1995) estimate that the feeding level provided under commercial conditions corresponds to 0.4-0.6 of what they would eat when fed unrestricted. Read, Baxter, Farish, and D'Eath (2020) offered sows a standard diet *ad libitum* for 3 days, and found an average intake per day of 5.67 (± 0.24) kg (with a maximum daily intake of 9.4 kg). Compared to the 2.5 kg standard ration offered, this means sows are normally provided with less than half (44.1%) of what they are motivated to eat.

As pregnancy progresses, the motivation to obtain feed increases (D'Eath, Tolkamp, Kyriazakis, & Lawrence, 2009); Terlouw, Lawrence, & Illius, 1991). Furthermore, the current trend for larger litters further exacerbates the sow's motivation to eat during pregnancy (D'Eath, Jarvis, Baxter, & Houdijk, 2018). Unfortunately, we did not find any published evidence whether food provision has increased at the same rate as litter size in the last 20 years, or if the gap between *ad libitum* intake and actual food provision widening.

However, while overfeeding sows by providing a conventional diet *ad libitum* is undesirable from an economic point of view, it may also lead to obesity and related locomotory and farrowing problems (Dourmad et al., 1994). Pregnant sows are therefore fed restricted for most of the gestation period, and since diet formulations are typically relatively nutrient and energy dense, the volume of the feed provided is insufficient to satiate the sow. Sows are continuously hungry (see e.g. Jensen, Pedersen, Theil, Yde, & Knudsen, 2012). This results in behavioural and physiological signs of hunger (D'Eath et al., 2018; Meunier-Salaün et al., 2001).

3.2 Behavioural effects of restricted feeding

Changes in the sow's behaviour reflect the effects of continuous restricted feeding of a conventional energy rich diet. Read et al. (2020) studied the behaviours of sows on a restrictive conventional diet, compared to sows fed *ad libitum*. They found that compared to *ad libitum* fed sows, the restricted sows spent less time in the bedded area, more time in the feeding stalls, less time lying laterally and ventrally but more time standing and walking (43–75% of the time). They also drank mainly after the morning meal, and less evenly over the day. *Ad libitum* feeding resulted in a considerable reduction in activity, with sows spending under 15% of their daytime standing and walking, and predominantly lying down.

There are comparable results regarding high versus low feeding levels of the same diet from other authors, e.g. Spoolder et al. (1995) and D'Eath et al. (2009) reviewed what is known in the literature. These reviews suggest that restrictively fed sows cannot control the initiation and termination of meals, as feed is provided at certain times and quickly runs out. They report increased rate of eating, shorter meal durations and generally higher levels of activity. The latter includes higher levels of foraging related oral activities. Drinker use is also higher (D'Eath et al., 2009).

In addition to these behavioural and physiological responses there are two important and very noticeable changes in behaviour of sows that are fed restricted, compared to sows that are fed ad libitum. They are an increase in aggressive behaviour and the development of stereotypies. These will be discussed in the next chapter.

4 Key areas to focus on regarding hunger of sows

Restricted feeding of sows results in behavioural and physiological signs of hunger, including increased competition for access to feed (aggression) and an increase in stereotypic behaviours. Competition over feed may be reinforced by several management and housing conditions that will be described in the following text. Hunger also leads to frustration, that may develop into stereotypies. How stereotypies are related to hunger is also described below.

4.1 Feed related aggression

- **Why is aggression between sows a problem?**

Aggression may result in physiological stress and immunosuppression (Fraser & Rushen, 1987). Social instability causes short term acute stress to both the aggressor and the receiver when fighting for rank, and prolonged chronic stress when access to resources is limited. Sows that lose many aggressive interactions show increased cortisol levels in response to a dose of ACTH as well as a higher baseline cortisol level, compared to sows that win most fights and sows that avoid aggressive interactions by showing submissive behaviours (Mendl, Zanella, & Broom, 1992). This suggests that losing aggressive interactions causes more physiological stress than avoiding aggression (or winning the fights). Skin lesions are the most prevalent physical outcome of aggression, and are likely to be painful. They may also cause secondary problems with infection. Finally, as described in the EURCAW-Pigs review on sow group housing and mixing (Schubbert, Spoolder, & Pedersen, 2020), aggressive interactions between sows may result in slipping and falling, in particular when sows are kept on a fully slatted floor, or on slippery solid floor. Slipping and falling may increase the risk of claw and leg lesions, which may cause lameness (Pluym, Maes, Van Weyenberg, & Van Nuffel, 2017). Heinonen, Peltoniemi, & Valros (2013) demonstrated a link between aggressive interactions and lameness shortly after introduction of sows into groups. Lameness affects sow welfare because it is painful. Furthermore, lame sows are not able to move normally and they may not be fit enough to compete with healthy sows for feed and water. This means they may suffer more from hunger and thirst (Madec, Cariolet, & Dantzer, 1986).

- **Are hunger and aggression linked?**

Although hunger and aggression are directly linked, it is important to note that restricted access to feed and other resources is only one of the two main causes of aggression between sows. Social instability is the other main cause.

Mixing unfamiliar sows in a group causes social instability. This is either by mixing individuals and forming a new group, or by adding new individuals to an existing group. Compared to fights over access to resources, aggression to establish social relationships is more intense, but subsides in the hours and days after regrouping (Spoolder, Geudeke, Van der Peet-Schwering, & Soede, 2009), especially if introductions take place on a weekly basis. Fights following mixing of unfamiliar pigs can last for several minutes (Mount & Seabrook, 1993), be repeated frequently during the first days following mixing and cause severe (skin) damage and stress. When pigs fight, they attempt to target the head, neck and ears of the opponent. Fighting additionally includes parallel or inverse parallel 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).

Competition for access to resources is often related to feed, although access to a comfortable lying space or access to water may also cause sows to be aggressive towards each other. When feed is available *ad libitum* competition is low, whereas competition is high when feed is scarce or if access to the resource is easy to control by one animal. Aggression usually involves forcing another animal to leave a feed resource, by biting the sides, rear or the vulva of the animal that is feeding or waiting to get access to the feed. M 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. Aggression related to competition for resources tends to continue even after stable social relationships are established.

Aggressive interactions resulting from competition are generally short in duration but frequent (Spoolder et al., 2009). The level of aggression depends on the type of feeding system (Spoolder et al., 2009): feeding systems that do not protect the sow whilst she is eating will inevitably cause problems, especially if the system 'rewards' displacement behaviours by making what is left of the feed ration available to the aggressor. A discussion of sow group housing systems and the way in which the animals are fed is in the EURCAW-Pigs review of sow group-housing systems (Schubbert, Spoolder, & Pedersen, 2020).

- **Does a reduced feeding level increase aggression?**

Several authors suggest that hunger causes increased aggression (e.g. Bench, Rioja-Lang, Hayne, & Gonyou, 2013). However, when using conventional diets, there is little evidence that this increase is caused by the level of feeding *per se*. Petherick and Blackshaw (1987) reviewed factors that affect pig aggression including the method of feeding. The design of feeding systems include several influencing factors, but when it comes to feeding level they only refer to one study (Graves, Graves, & Sherritt, 1978). These authors found that in weaned piglets the level of aggression between unfamiliar pigs increases when piglets are fed restrictively, in contrast to *ad libitum* feeding. The feeding levels as such did not cause differences in aggression. Similarly, there were no differences in aggression in sows fed on a high versus a low feed level in a dynamic group system with a deep bed of straw (Spoolder, Burbidge, Edwards, Lawrence, & Simmins, 1997). In this study

the introduction of new animals was the main cause of aggressive interactions between the sows. Greenwood, Dickson, & van Wettere (2019) compared sows fed a control diet (2.5 kg), a high-volume diet (4 kg), and two lignocellulose-enhanced diets. Although they found differences with the lignocellulose diets, there was no effect of feed level of the conventional diets on aggression. The review by D'Eath et al. (2018) also explicitly lists no references in relation to the actual amount of conventional feed.

There are some data that suggest a relationship between body condition score and skin lesions in sow herds. Edwards (1992) first suggested this relationship and refers to two studies in which several farms with restricted fed sows were investigated. Svendsen et al. (1990) found herds with a high average injury score (>0.84, compared to farms with <0.84) to also have less sows being scored as 'fat' (2.0% vs. 8.2%), and more as 'thin' (12.2% vs. 7.2%, respectively). The farms had a range of different feeding systems. Olsen et al. (1991) support this finding and report that when investigating 8 farms with Electronic Sow Feeders (ESFs) there was one where the sow condition was deemed to be 'over', six farms were 'normal' and one farm was 'under'. The average number of conflicts behind the feeders was scored as 3.4, 3.6-6.0 and 7.2, respectively. Both studies suggest that lower food intake is associated with more aggression. However, the study did not report on the actual feed intake, and it is also possible that the causal factor in both studies was the *access* to the food. Perhaps system design faults or dominant sows hindering access were causing fighting and lesions at the entrance of the feeding system, as well as a reduced feed intake and body condition in lower ranking sows.

Therefore, although it seems that restricting access to a concentrate feed (compared to unrestricted *ad libitum* feeding) may result in increased aggression if sows need to compete for access to the feeder, the actual amount of the restricted feed that is offered does not seem to affect the level of aggression by itself. This does of course not justify providing sows with a too low level of concentrate diet. It also does not imply that the volume of the diet is irrelevant: there are several studies that report that 'topping up' the restricted diet with roughage in the form of straw pellets or other bulky diets may help to reduce aggression. See further below for a discussion of dietary fibre and *ad libitum* feeding.

- **How can aggression be measured?**

Aggression can be measured directly by observing behaviour, and indirectly by counting the resulting skin lesions (Velarde & Geers, 2007). Velarde and Geers (2007) suggest that assessing aggressive interactions provides a valid way of evaluating welfare. According to Bateson and Martin (2021) aggressive behaviour needs to be recorded at group level, as opposed to an individual animal level, to associate each event with the details of the individuals involved. There are extensive ethograms developed to do this (e.g. Gonyou (2001)). However, Velarde and Geers (2007) (referring to Kelley, McGlone, and Gaskins (1980)) warn that for a comparison over time it is necessary to adjust for the time since mixing, and other aspects such as the time of day, the presence of feed and the ambient temperature. These may all affect the number of interactions, as may disturbance from the proximity of the observer. They conclude that behaviour observations are time consuming and it may therefore be more efficient to score skin lesions instead. Velarde and Geers (2007) suggests that these may either be observed on the farm or at the abattoir, although they warn that some factors (e.g. crowding) may increase aggression without causing additional lesions. It should also be noted that when mixing during transport or at lairage, lesions may result which are not associated with the aggression levels on farm.

There are several protocols for on farm scoring of lesions, and there is a EURCAW factsheet for on-farm skin lesion scoring in sows.

Fewer protocols are available for scoring at the abattoir, but there are increasing developments in this area for finishing pigs. Carroll et al. (2016) investigated at what point in the slaughter process lesions should be scored and they concluded that severe skin lesions, tail lesions and loin bruising are more visible on pig carcasses after they have been scalded and dehaired. This was followed up in different research projects. In the 'PigWatch' project, Spoolder et al. (2018) scored tail length and lesions automatically through an in-line camera at the abattoir. The system was used on pigs from 225 herds (250+ carcasses / batch). It generated a report per herd on the number of pigs, the prevalence of tail lesions and the fraction of short and very short tails. Therefore, as an alternative to scoring lesions on live animals, automating the assessment of skin lesions on pig carcasses looks promising. Of course, both studies are related to lesions on finishing pigs and not sows, but the principles can perhaps be extrapolated through future research.

4.2 Stereotypies

- **What are stereotypies?**

Stereotypic behaviours are behaviours that are repetitive, relatively invariant and do not seem to serve an obvious purpose. Often this behaviour is described as 'strange', 'abnormal' or 'out of context' (Lawrence & Terlouw, 1993). The animals' environment induces stereotypies and (confined) farm and zoo animals perform them. For sows, stereotypic behaviours can be redirected oral behaviours such as biting, nosing and licking of chains, floor or trough, 'sham chewing' with an empty mouth or excessive drinking and manipulation of the drinker (D'Eath et al., 2018). The occurrence of stereotypies indicates either a present problem or a past problem that has been resolved (i.e. a 'behavioural scar') (Wiepkema, 1992).

- **Development of stereotypies**

Stereotypies arise under circumstances in which animals are thought to be frustrated, bored, or aroused. These terms are difficult to define scientifically, nevertheless there is a link between stereotypies and poor welfare, as they are related to stress and negative affective states (Lawrence & Terlouw, 1993).

It is proposed that stereotypies have de-arousing properties that help the animal cope with stressful circumstances (Hemmings, Parker, Hale, & McBride, 2018). If pigs perform stereotypies when aroused, their heart rate reduces. Endogenous opioids, released during stereotypical behaviour, are involved in the underlying neurochemical mechanism and have the ability to reduce emotional distress (Loijens, 2002). Although stereotypies may have stress reducing capacities, they do not remove the cause of stress. Therefore, they are not a solution to the stress an animal is experiencing, but rather a coping mechanism to inadequate environmental conditions that do not meet the animal's needs (Wiepkema & Koolhaas, 1993).

When sows cannot respond to hunger in a species specific way (i.e. by performing appetitive foraging behaviour), they may develop oral stereotypies such as manipulation of the stall or drinkers, biting or chewing the bars of the stall, 'sham' chewing (chewing without feed in the mouth), or excessive drinking (Megan Verdon, Morrison, & Hemsworth, 2017). Stereotypies in unsatiated (feed restricted) gestating sows therefore often occur during the post feeding period and are negatively correlated with feed intake. This can be due to

the fact that feed intake is restricted and thus generating insufficient negative feedback from digestion to reduce feeding motivation (figure 1, right side). Additionally, consummatory behaviour that does not result in satiation creates positive feedback to stimulate more feeding motivation, appetitive and consummatory behaviour (figure 1, left side). Chronically unfulfilled feeding motivation results in a loop that can cause the development of stereotypies (Lawrence & Terlouw, 1993).

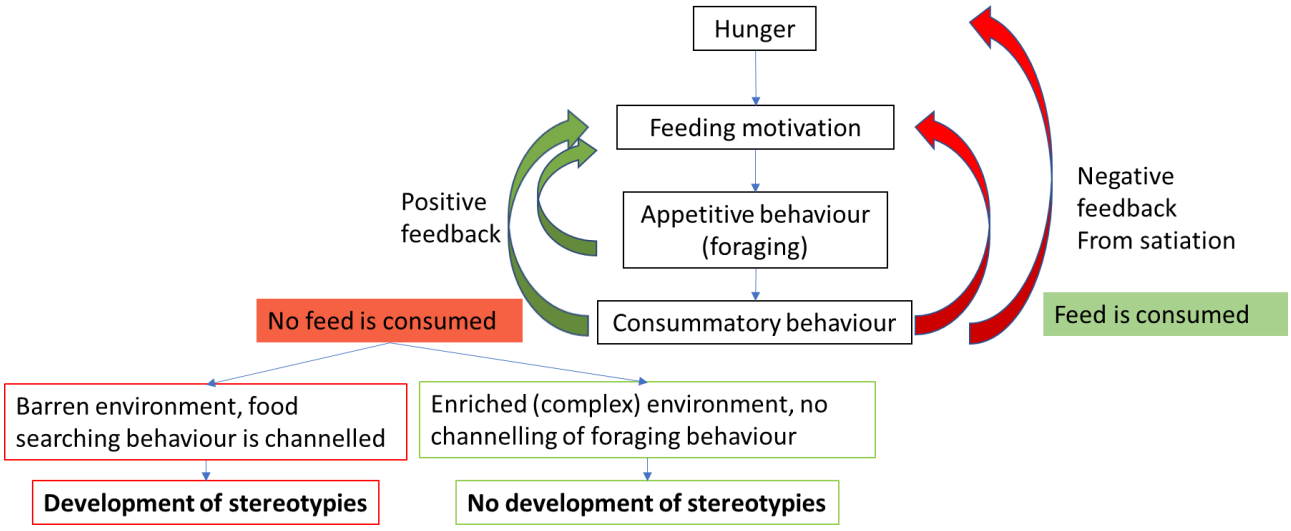

Figure 4.2.1. Model of the feeding motivation system of a pig (adapted from D'Eath et al. 2018). When feeding motivation is high due to hunger, the appetitive and consummatory behaviour stimulate more feeding motivation (green arrow). This positive feedback loop in a barren environment can cause the development of stereotypies. The lack of stereotypies in an enriched environment should not be interpreted to mean that sows are satiated, but simply that the environment allows more complex expression of foraging behaviour.

When pigs live under free-ranging conditions and feed intake is restricted, the risk of developing stereotypies is much lower due to the variety of environmental cues towards which they can direct foraging and consummatory behaviour (Figure 1). Hence, although stereotypies are highly related to hunger, it is not the sole cause of this behaviour. Whether stereotypies arise depends on the degree of constraint placed on the expression of behaviour and the (lack of) variability of the environment. This can result in the development of a strongly motivated and simplified behaviour that is allowed by the available incentives in the environment (channelling). When environments become less variable, foraging activities become more repetitive. Depending on the possibilities to perform behaviour within the environment, similar underlying motivations can result in different stereotypies (Lawrence & Terlouw, 1993).

- **Why do we see them in some animals and not in others?**

Not all pigs develop stereotypic behaviour under similar circumstances. Personality characteristics and genetic predisposition may also play a role (Gley et al., 2019; Schwaibold & Pillay, 2001). Since the development of stereotypies is related to feeding motivation and hunger, genetic differences in eating behaviour might also be involved in the onset of the stereotypies. Some eating behaviours such as the duration of meals and feeding frequency are heritable traits in pigs when food is available *ad libitum* (Fernández et al., 2011).

There are differences in the capability of pigs to adapt to stressors and in their physiological and behavioural responses to stress (Liu et al., 2018). Such differences are characterized as the personality or coping style of the individual animal. In general terms, a pig can be more proactive or reactive in controlling the environment and this coping style is found to be consistent over situations and related to physiological parameters (O'Malley et al., 2019). More proactive animals seem to be prone to the development of stereotypies in a suboptimal environment as a way to exert control and limit stress levels by inhibiting activity of the hypothalamus-pituitary-adrenal-axis (HPA-axis) (Geverink, Schouten, Gort, & Wiegant, 2003; Ijichi, Collins, & Elwood, 2013). In contrast, reactive animals respond in a passive manner that might seem to reflect less stress, but is related to a higher HPA response. As a result, non-stereotypic animals might even be more stressed by a suboptimal environment (Ijichi et al., 2013).

The underlying explanation for the difference in the development of stereotypies in relation to coping style lies in neurophysiological mechanisms (Gley et al., 2019), including the dopaminergic system that regulates the body's response to stress and reward. More proactive individuals tend to have higher levels of dopamine and stereotypic animals share this characteristic (Ijichi et al., 2013). Differences in the endogenous opioid system result in differences in how pigs process (stressful) stimuli, how they respond to challenges and thus how likely they are to develop stereotypies. Stereotypic behaviour seems to help the animal to cope with chronic stress. However, the de-arousing properties of stereotypies decrease with a longer duration of stress (Loijens, 2002).

How do we measure stereotypies?

When measuring stereotypies, it is important to keep in mind that different animals cope with stress differently. Therefore, the presence of animals with stereotypic behaviour is a sign of stress that might also affect animals that do not show the behaviour.

Stereotypies are measured by observation using ethograms describing the different types. The Welfare Quality® Assessment protocol for pigs (Dalmau et al., 2009) provides a short description of how to score stereotypies. More detailed descriptions are given by (Zonderland, De Leeuw, Nolten, & Spoolder, 2004) and shown in Table 4.2.1.

Table 1. Definitions of stereotypic behaviours (modified from Zonderland et al., 2004).

Behaviour	Definition	Picture
Sham chewing	Continuous chewing while no feed or substrate is present in the mouth. Also called vacuum chewing or saliva chewing. Saliva is often clearly visible around the mouth.	 
Tongue rolling	Sham-chewing with the tongue repetitively out of the mouth.	https://www.youtube.com/watch?v=AkoCPNF3njY 
Teeth grinding	Audible grinding of teeth, moving the lower jaw horizontally	*Picture unfortunately lacking*

Bar/trough/drinker biting	Repetitively nosing, rubbing, licking, or biting any metal component of the stall or pen bar/trough/drinker	 

An additional way to assess the presence of oral stereotypies is by observing the presence of “frothy” saliva. (Friedrich, Krieter, Kemper, & Czycholl, 2020). This naturally develops when cumulated saliva is moved in the mouth for a longer period of time, folding in air, which happens during the performance of oral stereotypies.

5 Minimising welfare problems: improved practices

There are several ways to reduce the welfare issues resulting from feed restriction. They divide into solutions that help to reduce the underlying problem of hunger and into those that mitigate the associated aggression and stereotypies.

5.1 Reducing the problem: increasing the feeling of satiety

Sows need to feel more satiated during gestation to reduce the root cause of the problem. Potentially, there are two approaches to achieve this: to change the frequency of feeding, and to change the type of feed offered to the animals. Their relative advantages and disadvantages are discussed below.

- **Frequency of feeding**

D'Eath et al. (2018) reviewed the effects of the timing and the number of meals on satiation in dry sows. Typically, sows are fed their ration once in the morning, or twice per day (morning and evening). They report work by Robert, Bergeron, Farmer, and Meunier-Salaün (2002) that suggests that stereotypic oral behaviour and vocalisations before meals and drinking, licking the empty feeder, and oral stereotypies after meals are more frequent when two meals were fed rather than one. Similar effects were found by Holt, Johnston, Baidoo, and Shurson (2006). Backus et al. (1997) also found that twice daily feeding is less favourable in terms of stereotypies compared to once per day. However, they considered it more favourable in terms of physiology (glucose and cholecystokinin). To support this, both Robert et al. (2002) and Jensen et al. (2012) found that the sow's motivation to feed was lower in the afternoon when sows were fed twice versus once daily, indicating better satiety in sows fed twice daily. Feeding less than once per day has also been tried: Douglas, Cunnick, Pekas, Zimmerman, and Von Borell (1998) fed sows on a conventional diet of 2 kg daily or 6 kg at an interval of once every third day. They found that reducing the meal frequency resulted in lower levels of oral behaviours including sham chewing, licking, feeding and excess drinking. The sows fed every three days were also less active every day. Feeding sows less than once per day is not allowed in the EU. It should be noted that wild pigs spend more hours foraging than any other active behaviour as they have to spent time to search for food compared to domestic sows, and therefore infrequent feeding is a major deviation from the sow's natural behaviour. These effects on feeding related behaviour may be due to the feedback mechanisms associated with foraging and feeding (see Figure 4.2.1), as feed provision initially increases the motivation to search for more feed (Terlouw, Wiersma, Lawrence, & Macleod, 1993).

To better understand the physiology of satiation, Douglas et al. (1998) looked at hormone levels in relation to once per three days ('interval') feeding. They found that cholecystokinin (which indicates satiation) was higher post-meal but lower pre-meal in interval-fed compared to daily fed dry sows. The blood glucose levels were similar in both groups before feeding, but was lower after feeding in daily fed sows compared to interval-fed sows. Therefore, the endocrine responses suggest a more stable pattern with increased frequency of feeding. In a relatively small study with 8 dry sows per treatment Manu, Lee, Keyes, Cairns, and Baidoo (2020) fed sows the same conventional ration in one, two or three meals per day, and recorded behavioural as well as stress hormone responses. They conclude that twice daily feeding appears favourable from a welfare point of view: it reduces the sows' total activity, feeding activity, and activation of the hypothalamic–pituitary–adrenal axis compared to once and three times feeding. Importantly, animals in this

experiment were kept in individual feeding stalls. Stress levels may be greater in group housed sows that are fed from an electronic sow feeding system more than once per day, as feeding time also includes the need to compete with other sows to gain access to the feeder.

Considering only the frequency of feeding, it seems best to feed sows daily: in 2 meals if feeding is simultaneous and protected, and in one meal if sows are fed sequentially or unprotected (e.g. floor feeding). Still, the frequency in itself has insufficient effect on satiation: sows will still be hungry most of the time. So other ways of increasing satiation in sows need to be explored.

Ad libitum feeding & increasing fibre in diets

According to D'Eath et al. (2018) there is a lot of research determining whether hunger is reduced while restricting energy intake to limit sow obesity and achieve good production. This work predominantly focussed on reducing the energy available in the diet, often by increasing dietary fibre. This way, sows should feel satiated without providing them too much energy. In principle, sows could even be fed *ad libitum* with a low energy dense diet (Ru & Bao, 2004).

Several approaches to lowering the energy density were investigated. Wet feeding systems for sows are used, but the amount of water in the diet only has a short-term effect on satiety. Reducing energy density is most easily achieved by replacing energy dense ingredients (carbohydrates and fat) with ingredients high in dietary fibre. Increasing feed volume per unit of energy can stimulate mechanoreceptors in the stomach wall enhancing meal termination (reviewed by Meunier-Salaün et al., 2001), with some fibres increasing their volume further as they absorb water and swell in the gut).

The feeling of satiety is affected by dietary fibre at various stages in the digestion process. D'Eath et al (2018) refer to this as the 'satiety cascade', which begins when sows are eating: feeds high in dietary fibre smell and taste different, and take longer to eat and chew (D'Eath et al., 2018). After swallowing, the process of digestion and gut passage time is affected by some fibres because of increased viscosity. Also, the fibre may physically prevent absorption of nutrients so that not all energy in the diet is digested. It can also delay the uptake of energy, until later in the digestive tract (Serena, Jørgensen, & Bach Knudsen, 2008). In addition to this, pigs also harbour active microbiota in the gut-intestinal system, able to ferment components of the dietary fermentable fibre fraction (Houdijk, 1998). In dry sows the amount of energy obtained through this process almost meets the energy requirements for maintenance (M. Verstegen, personal communication in (D'Eath et al., 2018)). In relation to satiety, the timing of energy release from this fermentation process is important. It is several hours after a meal, and thus coincides with the decline of blood glucose from digestion of starch and sugars in the stomach. Therefore it helps to reduce diurnal fluctuations in glucose and insulin and the feeling of hunger associated with reductions in blood glucose (Knudsen, 2001; Serena, Jørgensen, & Bach Knudsen, 2009).

High fibre diets generally benefit sow welfare compared to low fibre diets. They increase the duration of eating, reduce hunger, and heart rate responses to feeding (Robert, Rushen, & Farmer, 1997). According to De Leeuw, Bolhuis, Bosch, and Gerrits (2008), dietary fibres (irrespective of source) reduce stereotypic self-directed behaviours and substrate-directed behaviours, and to a lesser extent overall physical activity (Serena et al., 2008), indicating enhanced satiety shortly after a meal. Fibre is also likely to reduce stomach ulceration. Still, it should also be noted that the prolonged feeding periods require more feeder spaces to avoid an

increase in competition for access, and that sows generally show a preference for energy dense diets over high fibre ones.

5.2 Reducing the symptoms

Reducing aggression through appropriate housing and feeding systems

There are several housing aspects which may reduce the level of aggression over access to resources such as feed. In addition to avoiding aggression *per se*, it is probably even more important to reduce the impact that the aggression has on sow welfare. It will not always be possible to avoid conflicts, but leg problems due to slipping or falling during aggressive interactions are reduced if the floor is not too slippery and if the slats are in good condition. Bedding usually helps to absorb moisture and provide grip. Protruding elements (pen fittings) in e.g. walls and pen divisions should be removed, so that the animals can move freely and not be injured when suddenly moving and knocking against them. Rubber mats may also help to provide better grip (and lying comfort).

It is essential that sows have sufficient space to avoid aggression. Several studies report decreased aggression and injuries when increasing space allowance (Docking, Kay, Whittaker, Burfoot, & Day, 2000; Remience et al., 2008). It is likely that this is mainly due to increased opportunities to avoid aggression, e.g. by showing submissive behaviour (Jensen, 1982). The minimum space allowance needed to provide sufficient welfare to sows is not yet determined scientifically. Space requirements where interactions take place, for e.g. mating, fighting and fleeing, are the most difficult to estimate. Baxter (1985) estimated the amount of space sows need when engaging in a two-sided fight to be about 3.8 m^2 for a fight between two 200 kg sows. Fleeing to escape from aggression may involve flight distances from below 2.5 m up to incidences where sows were pursued for over 20 m (Edwards & Riley, 1986; Kay, Burfoot, Spoolder, & Docking, 1999). Two-sided fights and long pursuits are associated more with rank order fightings and less with fights over resource access. Nevertheless, its recommended to allow sows to avoid the aggressor and to flee from the situation rather than get blocked by pen walls or other obstacles.

Whilst feeding, sows should not be attacked by other sows. In systems where sows feed simultaneously, this is achieved by making sure that all sows stay with their allocated feed during the whole feeding period or by making sure they cannot displace other sows when they have finished their own rations. Examples of the first category of solutions are long trough feeding systems (for wet feeding pigs) in which the wet feed is spread, or trickle feeding systems which provide a prolonged and continuous access to feed to all sows at the same time. Whilst there is feed in front of the pig, the sow will not try to steal feed from a pen mate. And when the sow's feed is finished, so will the feed of the other members in the group.

In systems where a single amount of dry pelleted feed is presented to all animals at the same time, such as free access stall systems, fast eating sows finish their ration before the slow eaters. They may then try to steal feed. If the free access stall is long enough then it should be closed during feeding, so other sows cannot enter. If the side walls are only partially covering the length of the sow, then the longer the protecting side walls are the further the lesions are to the rear end of the attacked animal. Although some injuries will always be visible in these systems, measures need to be implemented to prevent poor welfare if severe biting occurs.

Usually these involve considerable changes to the housing systems, or even a complete replacement of the short stalls by another feeding method. Floor feeding systems (e.g. via dump or spin feeders that drop the entire ration for all animals on the floor of the pen) cannot be recommended for welfare reasons: they result in a lot of aggression. In addition, there is a lot of variation between sows in body condition, as dominant animals eat more than subordinates.

If sows are fed sequentially, it is important that they are protected from sows that are waiting to be fed. Electronic Sow Feeding (ESF) systems are the most common in this category. They allow feeding of large groups of animals without taking up a lot of feeder space in the building. In ESF systems the sow that is fed is usually fully protected, and receives an allocated amount of feed as identified by the feed computer. Waiting sows can only get access if they open the back door which remains locked until the fed sow leaves the feeding place and also for waiting sows that already finished their rations. Sows quickly learn there is no point in waiting for a closed door if they have been fed. In large stable groups they organise themselves in 'feeding orders' to avoid aggression. Dominant sows go first, subordinates feed later. Usually only a small number of sows wait at the feeder entrance. In dynamic groups these feeding orders also develop, but they are disrupted every time new sows are added to the group.

In all systems skin lesions should be monitored on a daily basis. Some degree of interaction between sows resulting in lesions is unavoidable. However, if changes in the incidence of lesions take place or if some individuals start to become more affected than others, action should be taken to provide better protection. Other signals to look out for are lesions to the rear of the body, particularly the vulva as it may indicate that an aggressor has found an effective way of getting access to feed allocated to another sow. Finally, uneven body condition in sows at the same stage of pregnancy is often a clear sign that there are differences in feed intake possibly over competition for access to feed.

Stereotypies

In reducing the development or onset of stereotypic behaviour it is important to acknowledge the sow's behavioural and physiological needs. Since feed restriction and restriction of foraging possibilities induce stereotypies **providing adequate feeding** and options to perform **behavioural needs related to feeding** are promising. From research on zoo animals we know that feeding enrichments increase exploratory behaviours and decrease abnormal behaviour (Wagman et al., 2018). Pigs similarly have a motivation to explore the environment for feed and recourses, but also explore novel features and environmental change. Therefore, the environment should provide materials to stimulate this behaviour. When materials contain edible parts they will stimulate curiosity and the motivation for foraging (Studnitz, Jensen, & Pedersen, 2007).

Offering environmental enrichment is a way to fulfil the sow's needs by providing her with environmental complexity and options for oral manipulation of substrates. According to the European Council Directive 2008/120/EC enrichments should be **edible, chewable, investigable and manipulable** to prevented development of stereotypies. Additionally, they should be provided in a way to **remain attractive** to the pigs (regularly replenished) and added in **sufficient quantity**. The best way to satisfy their motivation for foraging behaviours is when they can perform different foraging behaviours using different substrates.

Feed-restricted sows' motivation is mainly for appetitive foraging. Therefore, materials that contain edible parts are probably the most appropriate to prevent channelling and the development of stereotypies. Materials such as straw, hay, peat, or other roughages allow the sows to fulfil their rooting behaviour and reduce the occurrence of stereotypies (EFSA, 2014; H. A. Spoolder et al., 1995). Another way to prevent the channelling of behaviour is to increase the time spent on consummatory behaviour by making feed more complex to ingest, allowing the animal to express behaviour more similar to that expressed by wild conspecifics (Young, Carruthers, & Lawrence, 1994; Young & Lawrence, 1996). Additionally, the expression of appetitive behaviours has satiating properties in itself (Carlson & Carlson, 2007).

Besides environmental enrichment, attention should be given to the amount of **space restriction** that is placed upon the animal. Restricting space decreases freedom of movement or choices, and increases the probability of development of stereotypies through channelling (Lawrence & Terlouw, 1993).

6 Legal requirements

COUNCIL DIRECTIVE 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes

Article 4
Members States shall ensure that the conditions under which animals (other than fish, reptiles or amphibians) are bred or kept, having regard to their species and to their degree of development, adaptation and domestication, and to their physiological and ethological needs in accordance with established experience and scientific knowledge, comply with the provisions set out in the Annex.

ANNEX
Freedom of movement
7. The freedom of movement of an animal, having regard to its species and in accordance with established experience and scientific knowledge, must not be restricted in such a way as to cause it unnecessary suffering or injury. Where an animal is continuously or regularly tethered or confined, it must be given the space appropriate to its physiological and ethological needs in accordance with established experience and scientific knowledge.

Feed, water and other substances
14. Animals must be fed a wholesome diet which is appropriate to their age and species and which is fed to them in sufficient quantity to maintain them in good health and satisfy their nutritional needs. No animal shall be provided with food or liquid in a manner, nor shall such food or liquid contain any substance, which may cause unnecessary suffering or injury.

15. All animals must have access to feed at intervals appropriate to their physiological needs.

COUNCIL DIRECTIVE 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs

Article 3
1. Member States shall ensure that all holdings comply with the following requirements:

a) […]

b) 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 1,64 m2 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 %.

3. Member States shall ensure that the construction of or conversion to installations in which sows and gilts are tethered is prohibited. From 1 January 2006 the use of tethers for sows and gilts shall be prohibited.

4. 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. 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 2,4 m in length. 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.

5. Member States shall ensure that, without prejudice to the requirements laid down in Annex I, sows and gilts have permanent access to manipulable material at least complying with the relevant requirements of that Annex.

6. 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.

7. 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.

ANNEX I
CHAPTER I
GENERAL CONDITIONS
In addition to the relevant provisions of the Annex to Directive 98/58/EC, the following requirements apply:

4. 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. 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.

Acknowledgements

We would like to thank Laura Boyle Sandra Edwards and Simon Turner for their valuable contributions to this review.

7 References

Backus, G., Vermeer, H., Roelofs, P., Vesseur, P., Adams, J., Binnendijk, G., . . . van der Wilt, F. (1997). *Vergelijking van vier bedrijfssystemen voor guste en drachtige zeugen* (1385-3996). Retrieved from

Ball, R. O., Samuel, R., & Moehn, S. (2008). Nutrient requirements of prolific sows. *Advances in Pork Production, 19*, 223-236.

Bateson, M., & Martin, P. (2021). *Measuring behaviour: an introductory guide*: Cambridge University Press.

Baxter, M. (1985). Social space requirements of pigs. *Current topics in veterinary medicine and animal science*.

Bench, C., Rioja-Lang, F., Hayne, S., & Gonyou, H. (2013). Group gestation housing with individual feeding—I: How feeding regime, resource allocation, and genetic factors affect sow welfare. *Livestock Science, 152*(2-3), 208-217.

Brouns, F., Edwards, S., & English, P. (1995). Influence of fibrous feed ingredients on voluntary intake of dry sows. *Animal Feed Science and Technology, 54*(1-4), 301-313.

Carlson, N. R., & Carlson, N. R. (2007). *Physiology of behavior*: Pearson Boston.

Carroll, G., Boyle, L., Teixeira, D., Van Staaveren, N., Hanlon, A., & O'Connell, N. (2016). Effects of scalding and dehairing of pig carcasses at abattoirs on the visibility of welfare-related lesions. *Animal, 10*(3), 460-467.

D'Eath, R. B., Tolkamp, B. J., Kyriazakis, I., & Lawrence, A. B. (2009). 'Freedom from hunger'and preventing obesity: the animal welfare implications of reducing food quantity or quality. *Animal Behaviour, 77*(2), 275-288.

D'Eath, R. B., Jarvis, S., Baxter, E. M., & Houdijk, J. (2018). Mitigating hunger in pregnant sows. In *Advances in pig welfare* (pp. 199-234): Elsevier.

Dalmau, A., Velarde, A., Scott, K., Edwards, S., Butterworth, A., Veissier, I., . . . Bedaux, V. (2009). Welfare Quality® assessment for pigs (sows and piglets, growing and finishing pigs).

De Leeuw, J., Bolhuis, J., Bosch, G., & Gerrits, W. (2008). Effects of dietary fibre on behaviour and satiety in pigs: symposium on 'Behavioural nutrition and energy balance in the young'. *Proceedings of the Nutrition Society, 67*(4), 334-342.

Docking, C., Kay, R., Whittaker, X., Burfoot, A., & Day, J. (2000). *The effects of stocking density and pen shape on the behaviour, incidence of aggression and subsequent skin damage of sows mixed in a specialised mixing pen.* Paper presented at the Proceedings of the British Society of Animal Science.

Douglas, M., Cunnick, J., Pekas, J., Zimmerman, D., & Von Borell, E. (1998). Impact of feeding regimen on behavioral and physiological indicators for feeding motivation and satiety, immune function, and performance of gestating sows. *Journal of animal science, 76*(10), 2589-2595.

Dourmad, J.-Y., Etienne, M., Prunier, A., & Noblet, J. (1994). The effect of energy and protein intake of sows on their longevity: a review. *Livestock Production Science, 40*(2), 87-97.

Edwards, S. A. (1992). Scientific perspectives on loose housing systems for dry sows. *Pig Veterinary Journal, 28*, 40-51.

Edwards, S., & Riley, J. (1986). application of the electronic identification and computerized feed dispensing system in dry sow housing. *Pig News and Information*.

EFSA. (2014). Scientific Opinion concerning a Multifactorial approach on the use of animal and non-animal-based measures to assess the welfare of pigs. *EFSA Journal, 12*(5), 3702.

Fernández, J., Fàbrega, E., Soler, J., Tibau, J., Ruiz, J. L., Puigvert, X., & Manteca, X. (2011). Feeding strategy in group-housed growing pigs of four different breeds. *Applied Animal Behaviour Science, 134*(3-4), 109-120.

Fraser, D., & Rushen, J. (1987). Aggressive behavior. *Veterinary clinics of North America: food animal practice, 3*(2), 285-305.

Friedrich, L., Krieter, J., Kemper, N., & Czycholl, I. (2020). Frothy saliva—A novel indicator to assess stereotypies in sows? *Applied Animal Behaviour Science, 222*, 104897.

Geverink, N., Schouten, W., Gort, G., & Wiegant, V. (2003). Individual differences in behaviour, physiology and pathology in breeding gilts housed in groups or stalls. *Applied Animal Behaviour Science, 81*(1), 29-41.

Gley, K., Murani, E., Trakooljul, N., Zebunke, M., Puppe, B., Wimmers, K., & Ponsuksili, S. (2019). Transcriptome profiles of hypothalamus and adrenal gland linked to haplotype related to coping behavior in pigs. *Scientific reports, 9*(1), 1-14.

Gonyou, H. W. (2001). The social behaviour of pigs. *Social behaviour in farm animals*, 147-176.

Graves, H., Graves, K. L., & Sherritt, G. (1978). Social behavior and growth of pigs following mixing during the growing—Finishing period. *Applied Animal Ethology, 4*(2), 169-180.

Greenwood, E. C., Dickson, C. A., & van Wettere, W. H. (2019). Feeding strategies before and at mixing: the effect on sow aggression and behavior. *Animals, 9*(1), 23.

Heinonen, M., Peltoniemi, O., & Valros, A. (2013). Impact of lameness and claw lesions in sows on welfare, health and production. *Livestock Science, 156*(1-3), 2-9.

Hemmings, A., Parker, M. O., Hale, C., & McBride, S. D. (2018). Causal and functional interpretation of mu- and delta-opioid receptor profiles in mesoaccumbens and nigrostriatal pathways of an oral stereotypy phenotype. *Behavioural Brain Research, 353*, 108-113.

Holt, J., Johnston, L. J., Baidoo, S. K., & Shurson, G. C. (2006). Effects of a high-fiber diet and frequent feeding on behavior, reproductive performance, and nutrient digestibility in gestating sows. *Journal of animal science, 84*(4), 946-955.

Houdijk, J. (1998). *Effects of non-digestible oligosaccharides in young pig diets*: Wageningen University and Research.

Ijichi, C. L., Collins, L. M., & Elwood, R. W. (2013). Evidence for the role of personality in stereotypy predisposition. *Animal Behaviour, 85*(6), 1145-1151.

Jensen, M. B., Pedersen, L. J., Theil, P. K., Yde, C. C., & Knudsen, K. E. B. (2012). Feeding motivation and plasma metabolites in pregnant sows fed diets rich in dietary fiber either once or twice daily. *Journal of animal science, 90*(6), 1910-1919. doi:http://dx.doi.org/10.2527/jas.2010-3289

Jensen, P. (1982). An analysis of agonistic interaction patterns in group-housed dry sows—aggression regulation through an “avoidance order”. *Applied Animal Ethology, 9*(1), 47-61.

Kay, R., Burfoot, A., Spoolder, H., & Docking, C. (1999). *The effect of flight distance on aggression and skin damage of newly weaned sows at mixing.* Paper presented at the Proceedings of the British Society of Animal Science.

Kelley, K. W., McGlone, J. J., & Gaskins, C. T. (1980). Porcine aggression: measurement and effects of crowding and fasting. *Journal of animal science, 50*(2), 336-341.

Knudsen, K. B. (2001). The nutritional significance of “dietary fibre” analysis. *Animal Feed Science and Technology, 90*(1-2), 3-20.

Lawrence, A. B., & Terlouw, E. C. (1993). A review of behavioral factors involved in the development and continued performance of stereotypic behaviors in pigs. *Journal of animal science, 71*(10), 2815-2825.

Liu, H., Yi, R., Wang, C., Zhao, P., Zhang, M., Xu, S., & Bao, J. (2018). Behavior and physiology of two different sow breeds in a farrowing environment during late 35-day lactation. *PloS one, 13*(5), e0197152.

Loijens, L. W. (2002). *Stress, endogenous opioids and stereotypies in tethered pigs*. Ph.D., Wageningen University. https://edepot.wur.nl/121332

Madec, F., Cariolet, R., & Dantzer, R. (1986). *Relevance of some behavioural criteria concerning the sow (motor activity and water intake) in intensive pig farming and veterinary practice.* Paper presented at the Annales de Recherches Vétérinaires.

Manu, H., Lee, S., Keyes, M. C., Cairns, J., & Baidoo, S. K. (2020). Behavioral and cortisol responses to feeding frequency in pregnant sows under isocaloric intake. *Journal of animal science, 98*(8), skaa226.

Mendl, M., Zanella, A. J., & Broom, D. M. (1992). Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour, 44*(6), 1107-1121.

Meunier-Salaün, M., Edwards, S., & Robert, S. (2001). Effect of dietary fibre on the behaviour and health of the restricted fed sow. *Animal Feed Science and Technology, 90*(1-2), 53-69.

Mount, N., & Seabrook, M. (1993). A study of aggression when group housed sows are mixed. *Applied Animal Behaviour Science, 36*(4), 377-383.

O'Malley, C. I., Turner, S. P., D'Eath, R. B., Steibel, J. P., Bates, R. O., Ernst, C. W., & Siegford, J. M. (2019). Animal personality in the management and welfare of pigs. *Applied Animal Behaviour Science, 218*, 104821.

Petherick, J. C., & Blackshaw, J. K. (1987). A review of the factors influencing the aggressive and agonistic behaviour of the domestic pig. *Australian Journal of Experimental Agriculture, 27*(5), 605-611.

Petherick, J. C., & Blackshaw, J. K. (1989). A note on the effect of feeding regime on the performance of sows housed in a novel group-housing system. *Animal Science, 49*(3), 523-526.

Pluym, L. M., Maes, D., Van Weyenberg, S., & Van Nuffel, A. (2017). Risk factors for development of lameness in gestating sows within the first days after moving to group housing. *The Veterinary Journal, 220*, 28-33.

Read, E., Baxter, E., Farish, M., & D'Eath, R. (2020). Trough half empty–pregnant sows are fed under half of their ad libitum intake. *Animal welfare, 29*(2), 151-162.

Remience, V., Wavreille, J., Canart, B., Meunier-Salaün, M.-C., Prunier, A., Bartiaux-Thill, N., . . . Vandenheede, M. (2008). Effects of space allowance on the welfare of dry sows kept in dynamic groups and fed with an electronic sow feeder. *Applied Animal Behaviour Science, 112*(3-4), 284-296.

Robert, S., Bergeron, R., Farmer, C., & Meunier-Salaün, M.-C. (2002). Does the number of daily meals affect feeding motivation and behaviour of gilts fed high-fibre diets? *Applied Animal Behaviour Science, 76*(2), 105-117.

Robert, S., Rushen, J., & Farmer, C. (1997). Both energy content and bulk of food affect stereotypic behaviour, heart rate and feeding motivation of female pigs. *Applied Animal Behaviour Science, 54*(2-3), 161-171.

Ru, Y., & Bao, Y. (2004). Feeding dry sows ad libitum with high fibre diets. *Asian-Australasian journal of animal sciences, 17*(2), 283-300.

Schubbert, A., Spoolder, H. A. M., & Pedersen, L. J. (2020). *Review on group housing and mixing of sows (version 1.0)*, Wageningen: EURCAW-Pigs. https://edepot.wur.nl/537021

Schwaibold, U., & Pillay, N. (2001). Stereotypic behaviour is genetically transmitted in the African striped mouse Rhabdomys pumilio. *Applied Animal Behaviour Science, 74*(4), 273-280.

Serena, A., Jørgensen, H., & Bach Knudsen, K. (2008). Digestion of carbohydrates and utilization of energy in sows fed diets with contrasting levels and physicochemical properties of dietary fiber. *Journal of animal science, 86*(9), 2208-2216.

Serena, A., Jørgensen, H., & Bach Knudsen, K. (2009). Absorption of carbohydrate-derived nutrients in sows as influenced by types and contents of dietary fiber. *Journal of animal science, 87*(1), 136-147.

Spoolder, H., Burbidge, J., Edwards, S., Lawrence, A., & Simmins, P. (1997). Effects of food level on performance and behaviour of sows in a dynamic group-housing system with electronic feeding. *Animal Science, 65*(3), 473-482.

Spoolder, H., Zebunke, M., Labyt, E., Godin, C., Tallet, C., Prunier, A., . . . Larsen, H. D. (2018). *PigWatch: early automated detection of tail biting and aggression.* Paper presented at the 69. Annual Meeting of the European Federation of Animal Science (EAAP).

Spoolder, H. A., Burbidge, J. A., Edwards, S. A., Simmins, P. H., & Lawrence, A. B. (1995). Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. *Applied Animal Behaviour Science, 43*(4), 249-262.

Spoolder, H. A. M., Geudeke, M. J., Van der Peet-Schwering, C. M. C., & Soede, N. M. (2009). Group housing of sows in early pregnancy: A review of success and risk factors. *Livestock Science, 125*(1), 1-14. doi:https://doi.org/10.1016/j.livsci.2009.03.009

Studnitz, M., Jensen, M. B., & Pedersen, L. J. (2007). Why do pigs root and in what will they root?: A review on the exploratory behaviour of pigs in relation to environmental enrichment. *Applied Animal Behaviour Science, 107*(3-4), 183-197.

Terlouw, E., Lawrence, A. B., & Illius, A. W. (1991). Influences of feeding level and physical restriction on development of stereotypies in sows. *Animal Behaviour, 42*(6), 981-991.

Terlouw, E. C., Wiersma, A., Lawrence, A. B., & Macleod, H. A. (1993). Ingestion of food facilitates the performance of stereotypies in sows. *Animal Behaviour, 46*(5), 939-950.

Turner, S., White, I., Brotherstone, S., Farnworth, M., Knap, P., Penny, P., . . . Lawrence, A. (2006). Heritability of post-mixing aggressiveness in grower-stage pigs and its relationship with production traits. *Animal Science, 82*(5), 615-620.

Velarde, A., & Geers, R. (2007). *On farm monitoring of pig welfare*: Wageningen Academic Publishers.

Verdon, M., Hansen, C., Rault, J.-L., Jongman, E., Hansen, L., Plush, K., & Hemsworth, P. (2015). Effects of group housing on sow welfare: a review. *Journal of animal science, 93*(5), 1999-2017.

Verdon, M., Morrison, R., & Hemsworth, P. (2017). THE FEEDING BEHAVIOUR OF SOWS AND ITS RELATIONSHIP TO SOW WELFARE AND REPRODUCTION.

Wagman, J. D., Lukas, K. E., Dennis, P. M., Willis, M. A., Carroscia, J., Gindlesperger, C., & Schook, M. W. (2018). A work-for-food enrichment program increases exploration and decreases stereotypies in four species of bears. *Zoo biology, 37*(1), 3-15.

Wiepkema, P.R. (1992). Over belasting van ons vee. *Tijdschrift Diergeneeskunde, 117*, 141-145.

Wiepkema, P., & Koolhaas, J. (1993). Stress and animal welfare. *Animal welfare, 2*(3), 195-218.

Young, R. J., Carruthers, J., & Lawrence, A. B. (1994). The effect of a foraging device (The 'Edinburgh Foodball') on the behaviour of pigs. *Applied Animal Behaviour Science, 39*(3-4), 237-247.

Young, R. J., & Lawrence, A. B. (1996). The effects of high and low rates of food reinforcement on the behaviour of pigs. *Applied Animal Behaviour Science, 49*(4), 365-374.

Zonderland, J., De Leeuw, J., Nolten, C., & Spoolder, H. (2004). Assessing long-term behavioural effects of feeding motivation in group-housed pregnant sows; what, when and how to observe. *Applied Animal Behaviour Science, 87*(1-2), 15-30.

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Co-funded by the European Union