FRCAW literature review on the impact of partly or fully solid flooring systems on the welfare and behaviour of pigs

Request: What are the impacts of different solid flooring systems (partial/total), with or without the presence of bedding and/or foraging materials, on pig welfare and, particularly, on pig behaviours (manipulation, exploration, posture, interactions between animals, maternal behaviours, defecation behaviours) compared with a fully slatted floor?

The FRCAW's response will consider all categories of animal and all stages of development as defined by the pig industry.

Requested by: Compassion In World Farming (CIWF) France, Welfarm, Oeuvre d'Assistance aux Bêtes d'Abattoirs (OABA), La Fondation Droit Animal Éthique et Sciences (LFDA)

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Summary of the background as defined by the commissioning parties[1] **:** The need to explore is a very strong behavioural need in pigs. When this need cannot be fulfilled, pigs tend to redirect it towards other pigs, resulting in tail biting. To prevent tail biting, pig farmers still widely practise the systematic tail docking of piglets. However, Directive 2008/120/EC (European Commission, 2008) prohibits routine tail docking, stating that 'other measures' to prevent tail biting should first be taken. Of the possible measures available, enrichment of the living environment with litter (bedding) and/or foraging materials is proving an effective method to enable pigs to express their exploratory behaviour. However, this measure does not work well with fully slatted flooring, which is still the most common flooring type in pig farming. The problem lies in the fact that litter and/or foraging materials can obstruct the slurry evacuation system in fully slatted systems. Solid or partly solid flooring (more commonly known as partly slatted flooring) are useful alternatives to fully slatted floors, being more compatible with the addition of litter and/or foraging materials and therefore being more likely to allow pigs to express their exploratory behaviour.

Request by the commissioning parties: To produce a brief literature review comparing the effects of solid or partly solid flooring systems on welfare and, in particular, on the full range of pig behaviours, compared with fully slatted systems. More specifically, to examine:
- the factors enabling optimal use of fully or partly solid flooring systems and the obstacles and levers relating to their installation;
- the depth of bedding needed to allow animals to root;

[1] For the full text of the context as defined by the requesting parties, see Appendix 1.

- the availability of these types of flooring to pigs as alternatives to fully slatted floors at all stages of production, including sows;
- the factors that would enable optimum use to be made of solid or partly solid floors in the maternity and gestation stages, in order to meet the needs of sows and eliminate the need for piglet tail docking, while identifying the obstacles and levers relating to the introduction of such changes.

Please note:

- The bibliographical corpus employed for this overview is comprised of academic and grey literature. The process by which it was compiled is set out in Appendix 2. The items it contains have been selected by the FRCAW for the relevance of the information they provide and their inclusion does not necessarily indicate that the FRCAW shares all opinions expressed therein.

- In the English language version of this report, the Centre national de référence pour le bien-être animal (CNR BEA) is referred to by its English title (French Reference Centre for Animal Welfare, FRCAW), except in bibliographical references where the CNR BEA is cited as the official author of a work. The direct quotations of French works in the original report have been translated into English for ease of reading and, unless indicated otherwise, are the translator's own. To quote these sources, please refer to the official French language version of this report.

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Glossary (English version)

Agonistic interactions: ‘Any social interaction or engagement which involves threatening behaviour, aggression, fighting, or submission.’ (Young, 2019)

Animal welfare: ‘The welfare of an animal is the positive mental and physical state associated with the satisfaction of its physiological and behavioural needs and also with its expectations. This state varies according to the animal's perception of the situation.’ (Anses, 2018) translation, original in French).

Behavioural need: ‘Requirement which, if not met, leads to a reduction in welfare that may be significant enough to cause suffering. This impairment to an animal's welfare may be manifested through disturbed behaviours, increased risk of disease and/or a hormonal profile indicating a state of stress (adapted from Jensen and Toates, 1997). A behavioural need should be related to a motivation to express a particular behaviour.’ (Anses, 2015, p. 5, translation, original in French)

Bursitis: Bursitis is the acute or chronic inflammation of a bursa that occurs as a result of constant pressure and trauma to the skin over a bony protuberance. The membrane (or periosteum) covering the bone reacts by creating more bone (causing swelling) and the skin thickens until a soft, prominent mass appears. Symptoms include pain (particularly during motion or pressure), swelling and local tenderness (Dalal, n.d.). Bursitis can lead to broken skin, encouraging the development of a secondary infection (CNR BEA, 2024).

Caudectomy: Farming practice consisting of ‘amputating a portion of the tail’. [...] [It] is widely performed to reduce tail biting lesions in pigs reared under intensive conditions’ (EFSA Panel on AHAW, 2022a, p. 197). ‘Shortening of the tail leads to damage of the skin, muscles, bones, cartilages, blood vessels and nervous tissues’ (EFSA Panel on AHAW,2022a, p. 197).

Caudophagy: See ‘Tail biting’.

Comfort behaviours: Actions motivated ‘to maintain the high function and integrity of the integument (e.g. […] keep clean, scratch)’. (EFSA Panel on AHAW, 2022b, p. 14)

Environmental enrichment: Environmental enrichment is intended to meet the physiological and psychological needs of animals in captivity by introducing greater complexity to their environment through the use of various stimuli (Newberry, 1995; Näslund and Johnsson, 2016). ‘Enrichment can be classified into five (non-exclusive) categories […]: relational, feeding, occupational, physical and sensory enrichments’ (EURCAW-Ruminants & Equines, 2023; see also Veissier et al., 2024).

Feeding behaviour: ‘All the animal's actions directed towards finding, selecting and ingesting food in quantities that meet the body's energy and nutrient requirements’ ((Jean-Blain, 2002), translation, original in French). In the present report, it includes behaviours associated with foraging, feeding, chewing, swallowing and drinking.

Food-seeking behaviours: Investigative behaviour of a food-related nature. Animal behaviour dictionaries describe this as: ‘*behaviour involving searching for food*’ (Hurnik et al., 1999) or ‘*behaviour associated with searching for, subduing, capturing, and consuming food*’ (Mc Farland, 2006).

Fodder (or forage): ‘Any substance of plant origin used for the feeding and maintenance of livestock, with the exception of grain, in particular fresh or dried plants, stalks, leaves and roots from natural or created meadows’.(French Centre National de Ressources Textuelles et Lexicales), translation, original in French).

Fouling: The soiling of a solid floor by pig urine and faeces, linked to high ammonia emissions. At high temperatures, pig cleanliness levels are affected by fouling because animals choose to lie in soiled areas to cool down (Aarnink et al., 1997).

Investigative and exploratory behaviours: 'Investigative behaviour characterises the set of motor actions involved in inspecting an object or, more broadly, [an animal's] environment [...] using different sensory pathways depending on the target of the investigation.' (Anses, 2015, p. 5, translation, original in French). It becomes exploratory behaviour if the animal is exposed to a new object or environment. The latter is characterised by a state of alertness, a focus of the senses, and motor activity directed towards the new stimulus encountered (Boissy et al., 2007).

Litter: 'Straw or other types of fodder spread in barns, so that animals can lie on it'. (French Centre National de Ressources Textuelles et Lexicales), translation).

Lying (or resting) behaviours: All the actions and postures adopted by pigs when they are not active, in order to relax, sleep or recover (adapted from EFSA Panel on AHAW, 2022a).

Manipulable materials: According to Directive 2008/120/EC, *'material to enable proper investigation and manipulation activities*'. Materials that contribute to enrichment of an animal's living environment. Nesting materials are distinguished from manipulable materials in Directive 2008/120/EC. However, they will be treated as manipulable materials in the remainder of this report, given that some manipulable materials may fulfil several functions, including nest building (Anses, 2015, p. 6)

Manipulative behaviours: 'Behaviour involving the essentially tactile sensory pathway, using the mouth/snout or extremities of the limbs.' (Anses, 2015, p. 5, translation, original in French)

Motivation: 'Internal and external factors that interact to cause an organism [in this case, a pig] to act with a specific goal in mind. Motivation cannot be measured directly, but is inferred from quantifiable observations of the organism, behavioural expression and measurement of physiological indicators' (Anses, 2015, p. 5, translation, original in French).

Nest-building behaviours: A set of nest-building behaviours observed prior to farrowing, including 'rooting with the snout (movements of the snout on the floor or arranging of straw), digging/pawing, turning and carrying substrates (EFSA Panel on AHAW, 2022a, p.77).

Redirected behaviours: 'Behaviour directed towards a target other than the original target' (Anses, 2015, p. 14, translation, original in French).

Rooting behaviours: The animal pushes its 'snout into [the] straw, lifting it slightly with the rim of its disc' (Day et al., 2008).

Stereotypies: 'Sequences of limited and repeated motor actions with no obvious biological function' (Anses, 2015, p. 15, translation, original in French).

Tail biting (caudophagy): Biting of the tails of other pigs resulting in 'damage of the skin, muscles, bones, cartilages, blood vessels and nervous tissues' (EFSA Panel on AHAW, 2022, p. 197) or even in the loss of part of the tail.

Thermoregulatory behaviours: All those actions and behavioural responses that an animal adopts to maintain its body temperature (by reducing or increasing heat loss) within an optimal range, despite variations in environmental conditions.

List of abbreviations

ANSES: Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (French Agency for Food, Environmental and Occupational Health and Safety)

AHAW: Animal Health and Welfare

CNR BEA: Centre national de référence pour le bien-être animal (CNR BEA). See FRCAW.

EC: European Commission

FRCAW: French Reference Centre for Animal Welfare. Official English name of the CNR BEA.

EFSA: European Food Safety Authority

GOPEI: European Innovation Partnership Task Force

IFIP: Institut du porc (French Pig Institute)

INRAE: French Research Institute for Agriculture, Food and the Environment

BAT: Best Available Techniques

RMT: Réseau mixte technologique (joint technology network)

EU: European Union

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1. Context

1.1. Pig behaviours [2]

In semi free-ranging conditions (semi-freedom), pigs spend most of their active time during the day in activities related to exploration, foraging and feeding (CNR BEA, 2023). When reared indoors, most of their time is spent lying and resting, followed by feeding and manipulating their environment (CNR BEA, 2024).

1.1.1. Manipulative, investigative and exploratory behaviours

Since free-ranging pigs are highly motivated to perform foraging and exploratory behaviours (Stolba et Wood-Gush, 1989; Wood-Gush et Vestergaard, 1991), access to objects and materials for investigation and manipulation, including foraging, is essential to meet their needs. 'Pigs show a strong preference for digging with their snouts and manipulating materials with their mouths [...] These behaviours may [...] have an exploratory function or an alternative function not directly related to food. Appropriate substrates are soil for digging and chewable materials such as straw or twigs for manipulation.' (Anses, 2015, p.4). Investigative behaviour occupies more than 25% of a pig's activity time when it has access to plenty of bedding materials (Beattie et al., 2000). According to the Anses report on this topic (2015), 'investigative and manipulative behaviours can be associated with a pig's need for food; comfort (finding a resting area); nesting (for sows); investigating in its strict sense, associated with the animal's interest in identifying what is new [exploring] or in refamiliarizing itself with its physical and social environment (Studnitz et al., 2007) '. If the environment is not sufficiently varied or complex, this can soon result in a process of habituation that involves loss of interest in the environment and frustration (Wood-Gush et Vestergaard, 1991; Vanheukelom et al., 2012).

1.1.2. Resting behaviour

In partly slatted housing, it has been shown that a fattening pig spends more than 80% of its time lying down (Ekkel et al., 2003). This means that comfortable lying areas are essential for the animal's welfare. Where pigs have the opportunity to establish separate functional zones, the time they spend lying down is considered to be the best indicator of preference for an area of the pen or for a type of flooring (Pouteaux et al., 1983). Indeed, pigs prefer to rest and sleep in a dedicated, comfortable, clean, dry and protected area, sheltered from draughts, and where they feel safe. They adopt different resting postures according to the ambient temperature, lying on their sides in contact with a cool surface (lateral decubitus) when they are hot, and on their bellies (ventral decubitus) and huddled together when they are cold (Ducreux et al., 2002; Mormède et al., 2006).

1.1.3. Comfort behaviour

In pigs, comfort behaviours include grooming, scratching, rubbing the body against objects, parts of the enclosure or a conspecific, rolling on the floor, or stretching the body or part of the body (Camerlink, 2014; Li et al., 2020; EFSA Panel on AHAW, 2022b).

1.1.4. Eating behaviour

Pigs are highly motivated to search for food, especially when this is associated with ingestion (de Jonge et al., 2008). Even when food is freely available, pigs prefer to forage for food in a substrate rather access it directly or manipulate the substrate with no food present (de Jonge et al., 2008; Holm et al., 2008).

On farms, feeding behaviour depends on meal distribution times. Pigs are fed either in meals or using a continuous feeder. The feed intake of pregnant sows and gilts is, however, restricted to prevent the

[2] See Glossary for brief definitions of the various behaviours.

risk of obesity. It is therefore necessary to provide them with fibre or added straw in their feed to achieve satiety and avoid oral stereotypies linked to hunger (Lawrence et Terlouw, 1993).
Water intake occurs mainly at mealtimes (Ramonet et al., 2017) and the quantities ingested are dependent on thermal conditions (Andersen et al., 2014) and on the nature of the food in particular.

1.1.5. Elimination behaviour

Whenever possible, pigs establish a defecation area in the least comfortable part of the stall, away from the lying and feeding areas, and often close to a wall or corner (CNR BEA, 2023). At birth, piglets eliminate near the nest, moving further away as they grow older. Pigs tend to isolate themselves and sniff the environment before eliminating. Elimination occurs mainly after periods of activity and watering. The frequency of elimination decreases with age (Andersen et al., 2020).

1.1.6. Thermoregulatory behaviour

The thermal comfort range for pigs depends on an animal's age. It is estimated to lie between 28 and 32°C for piglets, between 15 and 25°C for late finishing pigs, between 15 and 24°C for pregnant sows and between 15 and 21°C for lactating sows (Marcon, 2016; IFIP, 2019a). Newborn piglets, having little hair or subcutaneous fat and a high surface-to-mass ratio, are particularly sensitive to cold and will huddle together or against their mothers to avoid heat loss (Gómez-Prado et al., 2022; CNR BEA, 2023). Adult pigs are less sensitive than newborns to cold. Because they have no sweat glands, pigs are unable to perspire, making adult pigs sensitive to heat and susceptible to heat stress. To regulate their temperature, they adapt their behaviours by panting, reducing their activity levels and food intake, seeking out cool, wet ground, lying on their sides rather than their bellies, and moving away from each other (Gómez-Prado et al., 2022; CNR BEA, 2023).

1.1.7. Nesting behaviour

Nest building is strongly motivated by an intrinsic set of characteristics in sows, who are likely to feel frustrated if they cannot move around and gather nest-building materials (Arey, 1992). Where nesting materials are available, the sow begins to construct her nest 24 hours before farrowing (Jensen, 1989) but will be at her most active between 4 and 12 hours before farrowing (Damm et al., 2003; Yun et al., 2014). The EFSA Opinion (2022a) identifies four functional behavioural elements of nest-building behaviour for sows and gilts, which it describes as follows: rooting and pawing material on the ground to make a depression; finding the material and carrying it back to the nest site; biting and tearing the material to give it the correct structure; and arranging the material into a heap at the nest site.

1.1.8. Interactions with congeners

Pigs are social animals living in stable hierarchical groups, with the hierarchy based on dominant/subordinate relationships. In pig farming, agonistic interactions occur mainly during weaning and re-grouping, when the mixing of animals disrupts the hierarchy, leading to fights and aggression during the first day. They also arise where there is competition for resources (Nielsen et al., 1995; CNR BEA, 2023). Where groups are stable, though, positive interactions between conspecifics predominate over agonistic interactions (Stolba and Wood-Gush, 1989; Rault, 2019; Clouard et al., 2022). Positive social interactions within the group include social sniffing, nose-to-nose contact and, in young animals, social play, all of which contribute to social recognition and the maintenance of group cohesion.

1.1.9. Redirected behaviour

According to the 2015 Anses opinion, frustration arising from the failure to satisfy a behavioural need can result in:

> degrees of agitation and redirected behaviours, i.e., behaviours directed towards a target other than the original target. For example:
>
> > - if the animals do not have the opportunity to explore or manipulate materials, they manifest investigative behaviours directed strongly towards both the physical environment and conspecifics. These include snouting, oral behaviours directed

towards the bellies of other piglets, known as ‘belly-nosing’ (Dybkjær, 1992), and ear and tail nibbling and biting, severing the tail in some cases (Beattie et al., 2000; Kelly et al., 2000; van de Weerd et Day, 2009; Scollo et al., 2013; Telkänranta et al., 2014; De Briyne et al., 2018). Behaviour directed towards conspecifics causes injuries and bites that can amount to cannibalism [in the form of tail biting, here] (Meunier-Salaün et al., 2009). (Meunier-Salaün et al., 2007);

- agonistic interactions occur between pigs in contexts other than social competition (Meunier-Salaün et al., 2007);
- play behaviours are reduced.

(Anses, 2015)

Focus on tail biting and docking

Tail biting involves the oral manipulation of one pig's tail by another, causing tissue damage. This abnormal behaviour can result in serious injury to the bitten animal (Henry et al., 2021).

> Two stages may be distinguished in the development of tail biting: the pre-injury stage, before any visual wound on the tail is present, and the injury stage, where the tail is wounded and bleeding. Tail-biting outbreaks are usually preceded by a period of tail-chewing or tail-in-mouth (TIM) behaviour, i.e. soft, nibbling manipulation of the tail of another pig [...] this period is mostly passed unnoticed by the farmer. The first stage may, more or less rapidly, result in a clear wound to the tail with associated bleeding. This is the injury stage, the ‘tail-biting outbreak’, as in this stage restlessness dramatically increases as other individuals become attracted to the blood and to the ongoing tail-biting activity in the pen.
>
> (EFSA Panel on Animal Welfare, 2007a, p. 20).

Tail biting is a multi-factorial problem and EFSA’s 2022 Opinion (2022a) has identified seven main risk factors for tail biting in animal husbandry, including the percentage of slatted floor and an insufficient supply of enrichment materials (summarised in CNR BEA, 2024, p. 67).

Tail biting has major repercussions for both animal welfare and farm profitability (Henry et al., 2021). To prevent tail biting, most farmers practise tail docking. However, tail docking causes acute pain and there is scientific evidence to suggest that it may lead to chronic pain in pigs (Tallet et al., 2019 ; Prunier et al., 2019, p.121-122) while failing to address the causes of tail biting (Valros, 2022). Furthermore, a survey in Finland reported that farmers considered an intact tail to be a good indicator of welfare (Valros et al., 2016). Routine tail docking is prohibited under European legislation, but is subject to a derogation when there is evidence of tail injuries on a farm despite prior application of alternative prevention measures (European Commission, 2008). However, reporting on France in 2019, the European competent authorities estimated that 99% of farmers continued to routinely perform tail docking under the exemption system (European Commission, DG(SANTE), 2019).

1.2. *Different types of flooring in farm buildings*

1.2.1. Fully slatted flooring

In a fully slatted flooring system the entire surface area of the enclosure is slatted and the openings between the slats allow effluent to pass through (Figure 1). Effluent is stored in a holding pit under the animals before being evacuated to an external pit. Construction materials vary and include concrete, cast iron, steel, aluminium, plastic and other polymeric materials, as well as combinations of materials. Concrete is the most widely found material in fattening and gestation pens, while plastic and metal are most commonly used in post-weaning and maternity pens (Anses, 2015). The widths of the slats and openings must be adjusted to fit the size of the animals' feet (EFSA Panel on AHAW, 2005) and are subject to regulatory standards (see Appendix 3).

This is the most common flooring type in the EU and France. An estimated 93% of post-weaning pig pens in France contained fully slatted floors in 2008 (Martin-Houssart, 2010).

Figure 1. Piglets being fattened on a fully slatted floor
at the Romillé French National Experimental Station run by IFIP.
Credit: Christophe Maitre, INRAE

1.2.2. Partly slatted flooring

In a partly slatted flooring system, 30 to 50% of the pen's surface area is slatted, while the remainder is formed of solid flooring (Anses, 2015). Pigs prefer to lie on the solid area (Figure 2) while dunging occurs in the slatted area. The optimal proportion of solid floor to slatted floor is still being researched. It would involve a compromise where sufficient slatted flooring is provided to maintain pen hygiene and keep the lying area clean, and sufficient solid flooring is available for the pigs to rest comfortably (EFSA Panel on AHAW, 2022a). For both systems involving slatted flooring (full or partial), rubber mats can be laid over the floor to improve the comfort of resting animals.

Figure 2. Pregnant sows lying on the solid area of a partly slatted pen
Credit: Chambre d'agriculture de Bretagne

1.2.3. Solid flooring

The surface of solid floors is unperforated and they are frequently made of concrete. Resting and excretion areas are generally separated structurally, and waste must be removed from the dunging area (EFSA Panel on AHAW, 2005). Cleaning must be carried out at frequent intervals, often daily, either manually or using automated scraper systems. Urine is often drained separately. Solid floors are used for all categories of pig, from weaning to slaughter, or in combination with other flooring types. These systems can be operated without bedding (bare solid floors, Figure 3), as scraped systems in which small quantities of straw are provided, or as deep litter bedding systems.

Figure 3. Fattening piglets on a bare solid concrete floor
Credit: Shutterstock

1.2.4. Solid floor with scraped litter

Here, the solid floor is made of concrete and the lying area is regularly replenished with straw. The fouled litter and effluent is scraped regularly (Figure 4). The addition of 50 grams of straw per pig per day ensures satisfactory drainage. The quantity should not exceed 100 grams, to avoid blockages or drainage problems (EFSA Panel on AHAW, 2007a).
One example of a solid floor system with scraped bedding was developed in the 1990s. Known as the straw-flow system, it is used for fattening pigs from 10 weeks (20-30 kg) through to slaughter (90-150 kg). In this system, the solid floor slopes downwards to the dunging area, which is also sloping, allowing the manure to flow down the slope.

Figure 4. Pregnant sows on solid flooring with scraped litter
Credit: Chambre d'agriculture de Bretagne.

1.2.5. Deep litter

As described by the EFSA in its Opinion (2007a), deep litter systems usually have a solid concrete floor. The entire pen area is covered with litter (Figure 5). Deep bedding (> 10 - 15 cm of materials) is made up of absorbent materials such as straw, sawdust, wood shavings, peat, etc., which accumulate during the rearing cycle. The accumulated composted livestock effluent is removed at the end of the cycle. An initial quantity of litter is required to start the microbial process, followed by frequent additions of fresh litter (avoiding disturbance). These steps together enable the deep litter to be properly maintained and the pigs kept comfortable (Chambre d'agriculture de Bretagne, 2012). To ensure that sufficient carbon

and oxygen are available to the microbial flora that break down the organic matter, the recommended surface area per pig on straw bedding is around twice that for slatted floors (IFIP, 2019b).
This type of system accounted for 5% to 7% of French pig farm buildings in 2012 (Chambre d'agriculture de Bretagne, 2012; Temple et al., 2012).

Figure 5. Fattening pigs on deep litter
Credit: Chambre d'agriculture de Bretagne

1.3. Main housing systems in France by pig category

1.3.1. Gilts and pregnant sows

In France, gilts and sows are generally housed in two areas in succession – the servicing area (where sows are inseminated, usually by artificial insemination, but also, more rarely, by mating with a boar) and the gestation, or pre-farrowing area (CNR BEA, 2024). In Europe, three different housing systems are used for the servicing area: individual indoor pens (90% of farms), indoor group housing, and outdoor housing. In France, experts have estimated that 'more than 66% of farms with females housed in individual crates in servicing areas keep the animals on concrete floors (solid or slatted) with no bedding or rubber mats. On most farms, a solid concrete floor is constructed at the front of the cages, with slatted flooring installed at the rear' (CNR BEA, 2024).

Once pregnancy has been confirmed, over 90% of French farms keep their sows in groups in indoor gestation areas with no outdoor access (CNR BEA, 2024). Here, the floor is usually constructed of slatted concrete, either wholly or in part.

1.3.2. Farrowing sows and unweaned piglets

Around five days before the expected farrowing date, the peripartum sows leave the gestation area for the nursery area. There, they can be housed in a variety of systems – maternity pens containing crates (permanent or temporary), free farrowing stalls, or free-range farrowing systems with, for example, larger farrowing pens (either individual or shared with other sows during the lactation period). In France, more than two-thirds of farms use farrowing pen systems with permanent crates, i.e., until the piglets are weaned at 21 or 28 days of age (CNR BEA, 2024). Permanent crates were developed to reduce the risk of piglets being crushed, but they affect the welfare of the sows in several respects - in particular by restricting their movement. To strike a balance between the safety of the unweaned piglets and the welfare of the sows, temporary crates (i.e. with a shorter period of constraint for the sow) have been developed, even though this is not a regulatory requirement. These crates are installed in individual pens - in which the sow can move around more freely, when she is not confined by the crate. Free farrowing and lactation pens, where the sow is free for most of the maternity phase (Ramonet et al., 2018a, 2018b) are being developed and now account for more than 75% of new maternity housing in

France (CNR BEA, 2024). According to equipment manufacturers, 75 to 100% of the stalls sold in 2022 were free-movement stalls (Chambre d'agriculture de Bretagne, 2024).

In maternity pens, partly slatted flooring is generally covered in plastic or metal. The sow's lying area is usually slatted, while the floor surface in the piglets' nest is solid (fitted with a rubber mat). This allows manipulable materials (long-stemmed straw, hessian) to be supplied in a rack placed above the safety rail or feed trough, without the materials falling directly through the spaces between the slats. A drained floor is located at the rear of the pen.

1.3.3. Weaners

In France, weaners are reared in groups in buildings with no access to the outdoors on over 90% of farms (CNR BEA, 2024). In 2023, the floors of post-weaning pens were estimated to be fully slatted in more than 80% of French farms (CNR BEA, 2024).

1.3.4. Fattening pigs

In France, fattening pigs are reared in groups in buildings without access to the outdoors (90-95% of fattening farms), or with access to the outdoors (<10%) (CNR BEA, 2024).They are generally housed on floors consisting entirely or partly of concrete slats (EFSA Panel on AHAW, 2007a).

1.3.5. Boars

Boars are housed in individual pens on more than 90% of French farms (CNR BEA, 2024). The floors of the pens are mostly partly slatted in concrete, and sometimes include a rubber mat or a limited quantity of bedding material.

1.4. Manipulable materials used in pig farming

1.4.1. Nature of the materials

Manipulable materials that allow pigs to express investigative and manipulative behaviours include, according to the European Commission (2008), the Anses (2015) and the Chambres d'agriculture de France et al., (2019) (European Commission, 2008; Anses, 2015; Chambres d'agriculture de France et al., 2019):
- organic materials of the type generally used in litter: principally straw, sawdust/wood shavings and peat, but also twigs and mushroom compost, all of which are spread out on the floor;
- nesting materials: manipulable materials such as litter, long-stemmed straw, chopped straw, alfalfa hay, silage or hay, and hessian are optimal nesting materials for pre-partum sows (Anses, 2015). Newspaper and shredded paper can sometimes be provided for sows.
- fodder-type materials: straw, hay and other fodder distributed in racks, feeders or troughs;
- deformable objects: e.g. rubber hoses, wooden sticks, ropes, hessian;
- non-deformable objects: balls, plastic balls or metal chains.

1.4.2. Physical characteristics

To meet the essential needs of pigs and be considered optimal, enrichment materials must be all of the following: safe, edible, chewable, investigable, manipulable by mouth, available in sufficient number or quantity to avoid competition problems, clean and hygienic (European Commission, 2016; Anses, 2018; CNR BEA, 2024). According to Studnitz et al. (2007), the exploratory and investigative behaviour of pigs is best stimulated by materials that are complex, easy to change, destructible, manipulable and contain edible parts. To be easily accessible, the materials should not be fixed, but neither should they lie loose throughout the pen. They must be regularly replaced or renewed because, while pigs are attracted by novelty, they quickly grow accustomed to and lose interest in the materials they are offered (Van de Weerd et al., 2003; Anses, 2015).

1.4.3. Impact of materials on the welfare and behaviour of pigs

Straw spread directly on the floor stimulates the natural investigative behaviour of pigs, who then display higher activity levels (Lyons et al., 1995; Beattie et al., 1996; Morgan et al., 1998; Beattie et al., 2000; Kelly et al., 2000; Beattie et O'Connell, 2002; Averos et al., 2010).
In the absence of suitable manipulable materials, pigs redirect their foraging and manipulative behaviours, manifesting non food-directed oral behaviours (sniffing, licking, chewing) towards pen fixtures or conspecifics (Hunter et al., 2001; Studnitz et al., 2007; Scott et al., 2007; Ruckli et al., 2024). The presence of organic substrates considerably reduces such persistent problematic behaviours among conspecifics, these being most often observed in weaners or fattening pigs. The EFSA Opinion (2022a) considers it possible to contain tail-biting outbreaks through the use of manipulable substrates, the effectiveness of which depends on their type (loose straw, softwood and hessian being the most effective), quantity (the Opinion recommends a minimum of 20 g of straw/animal/day), hygiene, accessibility (competition reduces effectiveness) and the manner in which these materials are distributed (for maximum effectiveness, organic substrates should be loose on the ground). For example, Van de Weerd et al. (2006) have shown that the provision of 5 cm of straw on the ground was more effective in limiting tail biting than the provision of manipulable objects (of the Bite Rite type).

In weaners, belly-nosing behaviour was also reduced when a foam rubber mat was placed against the wall or rubber nipples (Bench et Gonyou, 2006). Similarly, the risk of aggressive behaviour in response to manipulative individuals or the social hierarchy has been reduced in the presence of various enrichment materials such as tyres or pieces of wood at the end of a chain, chew toys chained to the wall, or loose toys placed on the floor, straw, earth, peat, etc. (Wood-Gush et Beilharz, 1983; Appleby et Wood-Gush, 1988; Schaefer et al., 1990; Blackshaw et al., 1997; van de Weerd et Day, 2009).

In unweaned piglets, access to paper and ropes reduces investigative behaviour directed towards the dam, who consequently develops fewer udder lesions (Lewis et al., 2006). In addition, the supply of enrichment materials before weaning would appear to reduce the subsequent risk of tail biting in weaners and fattening pigs, although results are contradictory on this issue (EFSA Panel on AHAW, 2007a; Anses, 2015).

Straw not only provides an effective form of enrichment, it also has other beneficial effects. The presence of straw has been observed to reduce the hypothermia that can result from loss of heat to the ground in newborn piglets (Pedersen et al., 2016). Several studies have also shown that straw improves the cleanliness of pigs and pens (Spoolder et al., 2000; Wallgren et al., 2020; Ocepek et Andersen, 2022), and the presence of straw reduces the risk of leg injuries compared with bare solid flooring (Tuyttens, 2005).

In these ways, manipulable materials not only satisfy the investigative needs of pigs, but also, in the case of bedding, contribute to their physical and thermal comfort in cold weather.

1.4.4. Impact of manipulable materials on the welfare and behaviour of pre-farrowing sows

The literature emphasises the positive impacts of adding materials such as straw, branches, sawdust or compost and hessian or rags to encourage and channel the increased activity classically observed before farrowing and associated with nesting behaviour (van de Weerd et Day, 2009; EFSA Panel on AHAW, 2014).
This behaviour is stimulated in different ways depending on the nest-building materials on offer. For example, Damm et al. (2000) reported that sows reared in semi-freedom with access to straw and branches were able to build more structured and functional nests than when only straw was provided. . Swan et al. (2018) found that the nesting behaviour of sows in gestation crates was stimulated to a greater degree if they were provided with newspaper rather than straw or wood shavings: the sows spent more time building their nests and less time biting the bars of their cages. Bolhuis et al. (2018) observed that pregnant sows in crates or free farrowing systems were more stimulated to build their nests if they were provided with hessian rather than straw. However, other authors felt that provision of

hessian did not have sufficient impact to satisfy the need for nest building (Markland et al., 2020). One recent study observed little nesting behaviour to occur in a group of pre-farrowing sows, despite the provision of different types of material (2.5 kg of long straw, or 2 sheets of newspaper each day, or a 65x77cm piece of hessian). The study's authors suggest that the small quantities involved might account for this (Hukkinen et al., 2024), a possibility already raised by (Damm et al., 2005). The EFSA Opinion (2022a) considers, with over a 66% certainty, that long straw, hay and silage are the most suitable nesting materials when supplied in sufficient quantity (i.e., when they allow sows to 'dig' in the ground). It would appear that when the straw is chopped up, sows display more stereotypies during nesting and less maternal behaviour after farrowing than when straw is supplied as whole stalks (Burri et al., 2009).. Data is lacking on the optimal quantity of manipulable materials to provide (EFSA Panel on AHAW, 2022a). For sows housed in free-range farrowing pens, Pedersen et al. (2015) suggest that straw (or other nesting materials) in excess of 1-2 kg per sow should be provided to meet the need for nest construction, to enhance the division of space into separate living areas, to improve thermal comfort for sows and piglets, and to help piglets dry off after farrowing.
Some authors conclude that, overall, the presence and quantity of nest-building materials, along with the moment at which they are supplied, have a greater influence on their use by the sow than their type (Damm et al., 2010; EFSA Panel on AHAW, 2014; Rosvold et al., 2019).

The provision of nesting materials makes it possible for sows kept indoors to express only certain elements of their innate nesting behaviour – it thus reduces, without totally eradicating, the sow's frustration at the impossibility of building a real nest. Indeed, in practice, even where nesting materials are provided, sows reared indoors are not really able to build a nest since it is not possible for them to dig in the earth (CNR BEA, 2024). Conversely, when sows are housed in individual crates, the absence of nest-building materials and the constraints this imposes on movement do not prevent the expression of nesting behaviours, even when such behaviours are empty, such as the rubbing of the snout against the ground, pawing movements and biting (Damm et al., 2003; Yun et Valros, 2015). Stereotypies (empty chewing, licking/nibbling of cage structures) may also be observed (Dantzer, 1986; Lawrence et Terlouw, 1993). These frustration behaviours are all the more pronounced when sows' feed ration (60-70%) is restricted to reduce the risk of obesity. Where the ration is reduced, organic fibrous materials can also be a source of satisfaction for appetitive behaviours (foraging and ingestion) by creating a feeling of satiety conducive to welfare (Meunier-Salaün et Bolhuis, 2014; EFSA Panel on AHAW, 2022a; CNR BEA, 2024).

1.4.5. Choice of bedding materials

Although straw is still the most commonly-used bedding in pig farming, farmers are increasingly faced with problems of quality and supply, bringing additional costs (Chambre d'agriculture de Bretagne et al., 2012). Some alternatives to straw, such as wood shavings, sawdust or peat, are beneficial to pig welfare and health (keeping animals dry and clean, providing protection against slippery or abrasive floor surfaces, providing comfortable bedding, stimulating rooting and nesting behaviour, etc.) and can rival straw in terms of absorption and drainage (SRDP Farm Advisory Service, 2024). In addition, peat (Rosvold et Andersen, 2019) or mushroom compost (Durrell et al., 1997; Elmore et al., 2011) have the advantage of being unlikely to block slurry drainage channels. Peat is three to four times more absorbent than straw (SRDP Farm Advisory Service, 2024). Its capacity to bind ammonia is greater than that of straw bedding, wood shavings or sawdust, enabling a reduction in ambient ammonia levels and producing manure with very good fertilising power (Kemppainen, 1987). The structure of peat is similar to that of soil and stimulates the exploratory behaviour of pigs, who use it for digging, rooting and wallowing (Studnitz et al., 2007, Vanheukelom et al., 2011). It also stimulates nesting behaviour in sows, although this is less complete than with straw, which is suited to all stages of nesting (Rosvold et al., 2018). Like straw, these alternative substrates can help to reduce undesirable behaviours (oral behaviours directed at conspecifics and aggression) and promote rest (Beattie et al., 1995, 2001; Durrell et al., 1997). In a preference test, fattening pigs preferred peat, mushroom compost and sawdust, followed by sand, wood bark and straw, with bare concrete being the least preferred option (Beattie et al., 1998). In another study, wood shavings and the bark of rice or coffee used in tropical climates generated investigative behaviour and reduced aggressive behaviour in weaners and pigs (Caldara et al., 2014; Hötzel et al., 2009).

1.4.6. Disadvantages of manipulable materials

Manipulable materials may present a health risk. For example, straw may have become contaminated by pathogens during harvesting, storage or transport and wood and wood shavings may have been treated and contain chemical pollutants. Peat has also been demonstrated to be frequently contaminated, despite the fact that it is a material of choice in maternity pens (Matlova et al., 2005). It is possible for poor quality objects to become damaged and cause mouth lesions. As a consequence, it is necessary to check the safety of manipulable materials, to comply with biosafety rules when introducing them, and ensure their traceability (Anses, 2015). Last, the objects used for enrichment must be changed regularly to avoid loss of interest through familiarity (Van de Weerd et al., 2003).

1.5. Regulatory framework

The main passages of the European and French regulations that directly or indirectly affect the choice and design of flooring and the provision of enrichment materials in pig farming are provided in Appendix 3.

2. Impacts of floor types on pig welfare and behaviour

2.1. *Fully slatted*

2.1.1. Advantages of fully slatted flooring

Comfort and hygiene

Slatted floors contribute to keeping animals clean by allowing faeces and urine to pass quickly through the openings, thereby helping to keep the lying area dry. As a result, both pigs and pens are cleaner on fully slatted floors than on partly slatted floors (Guingand, 2003). When given the opportunity to do so, pigs try to keep their resting and feeding areas clean (Nannoni et al., 2020).
Slatted floors are cooler than solid floors. In hot weather, pigs prefer to lie on slatted rather than solid floors; slatted floors thus contribute to the thermoregulatory behaviour of pigs in hot weather (Hörning, 2007).

Health

As a result of the improved hygiene of both animals and their environment, the prevalence of salmonella (Davies et al., 1997; Nollet et al., 2004) and other bacteria (Rantzer et Svendsen, 2001) is reduced on fully slatted floors compared with partly slatted floors.

2.1.2. Disadvantages of fully slatted floors

Comfort and hygiene

When the ambient temperature is below the lower limit of the pig's thermal comfort zone, the open construction and associated ventilation system of a fully slatted floor reduce the effectiveness of its thermoregulatory behaviours under winter conditions (Fraser, 1985; EFSA Panel on AHAW, 2005, 2022a).
Pigs on fully slatted floors have a high risk of developing bursitis, which affects lying comfort. For example, in the study by Courboulay et al. (2009) the percentage of pigs with bursitis was 82% for animals reared on fully slatted flooring, compared with 14% for those reared on solid flooring with bedding.

Expression of behavioural needs

With fully slatted floors, use of enrichment materials such as litter or fodder is problematic as the materials fall through the slatted floor openings and can clog the openings and manure drainage systems (Tuyttens, 2005; Day et al., 2008). However, the materials that are compatible with slatted flooring are also less effective in satisfying the animals' exploratory behavioural needs. Also, stocking densities are often higher in fully slatted systems than in partly slatted or solid flooring systems (IFIP, 2019b; Nannoni et al., 2020; EFSA Panel on AHAW, 2007b, 2022a). The combination of these two factors (high stocking densities and lack of adequate enrichment) constitutes a high risk that behaviours will be redirected towards conspecifics (Guy et al., 2002) and a particular risk of tail biting among weaners and fattening pigs (see Section 1.4.3) (EFSA Panel on AHAW, 2007a, 2022a).

Health

Certain characteristics of slatted floors, such as their uneven surface, reduced bearing surface and incompatibility with bedding, increase the risk of leg injuries and lameness (KilBride et al., 2009a). A key factor when choosing slatted flooring is the ratio of the slat and slot dimensions to the size of the pig's feet at a given age. When these do not suit the size of a pig's foot, slatted floors can injure animals by trapping their feet and tearing off their claws (EFSA Panel on AHAW, 2022a). The dimensions appropriate to different categories of pig are defined in the European regulations for concrete slatted floors (European Commission, 2008; see Appendix 3).
The quality of the slatting (design, physical properties, abrasiveness, humidity) also plays a major role in foot and leg injuries. For example, flooring constructed of bare woven wire or expanded metal with a

low ratio of slats to openings (wire mesh) significantly increases leg injuries unless it is plastic coated (Lewis et al., 2005).
Soft tissue and tail lesions (Courboulay et al., 2008; Ramonet et Villain, 2021) ear lesions (Courboulay et al., 2008) and lameness (Courboulay et al., 2009; KilBride et al., 2009a, 2009b) are more frequent in fattening and finishing pigs reared on fully slatted floors than those raised on bedding. Lactating sows housed in farrowing crates have more leg and teat injuries on slatted floors than they do on solid floors with litter
(Edwards et Lightfoot, 1986).
In fully slatted systems, the ammonia emissions from the slurry pit are high (European Commission. Joint Research Centre., 2017, p. 365). If ventilation is inadequate, this can lead to poor air quality and to respiratory and eye problems for the animals, the severity of which increases with the concentration of the ammonia (EFSA Panel on AHAW, 2014, 2022a). In addition, high concentrations of ammonia in the air are a risk factor for tail biting (Scollo et al., 2016; EFSA Panel on AHAW, 2022a).

2.1.3. Possible ways of improving fully slatted housing

Although the EFSA Opinion (2022a) recommends that solid or partly slatted floors are to be preferred when constructing new buildings, improvements can also be made in existing buildings.

Control of a building's atmosphere

In order to prevent the respiratory and ocular disorders associated with high concentrations of ammonia and to reduce the ambient temperature to levels that are comfortable for pigs during hot weather, effective ventilation must be provided (INERIS, 2018; EFSA Panel on AHAW, 2022a). To prevent health risks to pigs and humans, the ammonia level in the air must be kept below 10 ppm (Colina et al., 2000). This can be achieved by reducing the surface area of the volatising slurry, keeping floors clean and regularly pumping slurry away to a covered outdoor storage facility (Espagnol et al., 2015), and by separating urine from faeces (European Commission Joint Research Centre, 2017). According to the BATs (Best Available Techniques) set out in the European Commission's Implementing Decision (EU) 2017/302 of 15 February 2017, if pits are deep enough, they can be used in combination with a system for air scrubbing, slurry cooling and/or slurry pH reduction (European Commission, 2017).. Lowering the ambient temperature also reduces ammonia and greenhouse gas emissions. A study of fattening pigs in temperature-controlled units has shown that lowering the building temperature from 22°C to 18°C reduced ammonia and methane emissions by 36% and 54% respectively, and slurry production by 25%, with no significant effects on zootechnical performance (Guingand et al., 2024). The effects of ambient temperature and ventilation on ammonia and greenhouse gas emissions are interdependent: increasing the air flow rate lowers the air temperature. Well-designed ventilation and the control of flow rates and circulation patterns (achieved by lowering the building temperature and reducing air circulation speeds across the surface of the slurry and at ground level) can reduce ammonia emissions from buildings (European Commission. Joint Research Centre, 2017, p. 366).
Ammonia and greenhouse gas emissions in fully slatted buildings can be controlled. In particular, the physical characteristics of the slatted floor, including the porosity and roughness of the concrete (application of a smoother surface material to slats allows manure to fall faster into the pit without sticking), and the shape and width of the slats and openings between them, influence the floor's drainage properties. A well-ventilated, cool area should be provided for dunging to restrict emissions at pig height. The positions of feed and drinking troughs, installation of solid partitions around the intended lying area to reduce draughts and increase comfort, and perforated partitions in the area intended for elimination to lower the temperature, all help to influence where the pigs will urinate and defecate and control how much of the surface area is soiled. Increasing the surface area per animal and installing a sprinkler system to cool the animals could also prevent an increase in emissions (European Commission Joint Research Centre, 2017, pp. 36§_368).
Last, the manure disposal system designs described in the BATs provided by the European Commission Joint Research Centre (2017) are available for consultation. Manure should be managed in such a way as to maintain indoor air quality (by controlling the release of ammonia) and the health status of the animals (by preventing the redistribution of pathogens from the manure via the ventilation system).
(European Commission Joint Research Centre, 2017, p.369 and ff.; IFIP, 2019b).

Environmental enrichment

The addition of litter helps to meet the exploratory behavioural needs of pigs and considerably reduces outbreaks of tail biting (see Section 1.4.3). The issue is, therefore, whether sufficient manipulable materials can be provided to pigs in farming systems already fitted with fully slatted floors.

- Conditions for the use of litter or fodder on a fully slatted floor

Recommendation 15 in Spoolder et al. (2011, p. 75) states that, even where pigs are housed on fully slatted floors, small amounts of straw or other manipulable materials should be provided to improve their welfare. Indeed, it has been shown that the provision of straw, either on the floor or in racks, is not incompatible with slatted floors, so long as it is chopped and provided in small quantities (⩽ 20 g/pig/day) to avoid blocking slurry-handling systems or building up in the slurry pit (D'Eath et al., 2014). According to Jensen et al. (2008), when given the choice, pigs show no preference between chopped straw or straw kept as long stalks, although it would appear that lower levels of aggression (Lahrmann et al., 2015) and tail biting (Day et al., 2008) are to be observed in groups of pigs when straw with long stalks (>7cm) is supplied. The IFIP has observed and analysed the use of small quantities of straw chopped into short stalks (4 cm) for fattening pigs reared on fully slatted floors in two different distribution systems: in racks at a rate of 8.3 g/pig/day (with a container on the slatted floor below to help keep the straw from falling through the slats); or using a 'nourripaille' (a single-animal feeder where straw can be accessed through bars on the lower part) at a rate of 10.1 g/pig/day. Racks would appear to assist the animals in their use of straw, with fewer tail and ear lesions, whereas limited access and soiling make the 'nourripaille' system less beneficial (Courboulay, 2019). For a rack to be usable by pigs, both the height at which it is positioned and the size of its openings must be adjusted to suit the size of the pigs and their snouts respectively, enabling them to access the enrichment material easily and ensuring that the material does not fall directly to the ground (EU Platform on Animal Welfare, 2023).

The distribution of straw on slatted floors does, however, require an appropriate waste disposal system and is not compatible with buildings equipped with a simple holding pit for slurry with no engineered modifications. In the floating slurry technique, used in the IFIP trial, the base of the holding pit is covered by a small quantity of water (40 L/pig) to prevent sedimentation of solids and help the effluent to drain during emptying. The advantage of this technique is that no modifications need be made to existing buildings with slatted floors (Guingand et Courboulay, 2016). There are other drainage techniques available, but these must be incorporated into the design of the building. They may include larger diameter discharge pipes, slurry pumps fitted with chopper blades, use of smaller, faster-flowing slurry systems, and progressive cavity pumps suitable for viscous liquids (D'Eath et al., 2014). Mechanical evacuation systems equipped with a V-shaped scraper that follows the contour of the bottom of the pit permit the frequent evacuation (6 to 12 times a day) of manure from the holding pit for composting, while separating the urine (Loussarn et al., 2014). Use of this system made it possible to supply straw (30 g/pig/day) in racks to fattening pigs raised on fully slatted floors without blocking the drainage system (Caille et Loussouarn, 2016).

- Supply of manipulable objects

In practice, few French farmers who use fully slatted floors currently provide straw or other loose organic materials for enrichment, instead offering alternative enrichment such as objects. Non-destructible objects that are provided loose within the pen (balls) quickly become soiled and fail to hold the interest of the animals unless they are frequently replaced (Moinard et al., 2003; Scott et al., 2007; Studnitz et al., 2007; Vanheukelom et al., 2012). Further, chains and other non-destructible materials are excluded from the optimal category of materials set out in the Council of Europe Directive (European Commission, 2008). The EFSA Opinion (2022a) considers straw, hay and silage to be more effective in reducing tail biting than ceiling-hung or wall-mounted enrichment materials; it is also more effective than pressed straw blocks and dispensers that require prolonged manipulation by the animals to obtain the substrate. However, despite the fact that they do not satisfy pigs' feeding and foraging behavioural needs as much as fodder, deformable objects suspended at animal level (to avoid soiling) or fixed to the floor (offering pigs the possibility of manipulating them in a prone position) such as pieces of wood, rubber hoses, or ropes do provide interest for the animals (Bracke et al., 2006; Trickett et al., 2009; Courboulay, 2019).. One study reported that wooden sticks (5-10 cm in diameter) suspended from horizontal chains at the height of the animal appeared to be effective in reducing tail biting (Telkänranta et al., 2014), but soft woods (such as pine) are to be preferred over hard woods (such as acacia) because the material is more chewable, deformable, ingestible and destructible (Telkänranta et al., 2014; Caille et Loussouarn, 2016).

Ideally, for purposes of pig welfare, different enrichment strategies should be combined, since increasing the number of materials in a pen increases their use by the pigs (Caille and Loussouarn, 2016), thereby reducing unwanted behaviours. On fully slatted floors, where only a small quantity of straw (preferably chopped) can be added, environmental enrichment can be provided by the addition of straw in racks and of deformable objects that are hanging and/or fixed to the floor.

- Installation of matting

The addition of rubber (or plastic) mats (Figure 6) in fully slatted pens would improve the sleeping comfort of the animals, particularly for gestating sows (Elmore et al., 2011), suckling sows and their piglets (physical and thermal comfort) (Boyle et al., 2000; Baxter et al., 2011), while providing solid surfaces that allow the small quantities of litter provided to be retained, ensuring that it remains available to the animals without clogging the slats (EFSA Panel on AHAW, 2022a). Rubber mats placed on a fully slatted floor also reduce the risk of leg injuries in fattening pigs (Falke et al., 2018) and reduce the occurrence of aggressive behaviour when mixing primiparous sows (Lagoda et al., 2021). A note of caution is sounded by French experts, though, with the reminder that ‘if used, rubber mats must be cleaned regularly to prevent them from becoming breeding grounds for bacteria that could contaminate’ the animals. (CNR BEA, 2024)

Figure 6. Pregnant sows using a rubber mat on a fully slatted floor
Matting used as a resting area. Credit: Anses, photograph from Réussir porc (2024)

Box 1. Key points to remember about fully slatted flooring systems

When designing the building

- When designing a new building, a solid floor with litter or a partly slatted floor is preferable.
- Plastic or plastic-coated slats for piglets, or slats formed of non-abrasive concrete for larger animals, are preferable to reduce the risk of injury.
- Gaps between the slats should be adjusted to suit the size of the animals. It should never be possible for their feet to become trapped in them.
- Slats made of metal wire should be avoided

Opportunities for environmental enrichment

- Fully slatted flooring does not permit a sufficient supply of loose substrates (straw) for the expression of exploratory and nesting behaviours. As a result, the risk of tail biting on fully slatted floors is higher than on other types of flooring, all other conditions being equal.
- Straw should be supplied using racks with a container placed underneath to prevent it falling too quickly through the slatted floor into the slurry pit.
- Chopped straw is less likely to block openings and the slurry evacuation system than whole straw. It reduces the risk of tail biting but is not an optimal nesting material for sows.
- A suitable enrichment strategy for fully slatted floors could be the provision of additional straw using racks and deformable objects that are suspended and/or fixed to the floor.
- When chopped straw is provided, use of the floating slurry technique facilitates waste evacuation without having to modify building design.
- The addition of rubber (or plastic) mats on fully slatted floors facilitates the supply of enrichment materials at ground level, reduces the risk of leg injuries and improves animal comfort while they are resting.

Control of the building's atmosphere

- The building must be efficiently ventilated and the slurry regularly evacuated to ensure that ammonia levels in the air are kept below 10 ppm.

2.2. *Partly slatted flooring*

2.2.1. Advantages of partly slatted floors

Comfort

A lying area with solid flooring provides greater comfort for pigs when their temperature is within thermoneutral parameters.

Expression of behavioural needs

Partly slatted floors allow pigs to divide their space into several different living areas, including a lying area (solid floor) and an evacuation area (slatted floor). The surface area required per animal is therefore greater than it is on a fully slatted floor (EFSA Panel on AHAW, 2005). It is probable that pigs do not select a specific place to eliminate. Rather, it is thought, they opt to use the most comfortable area (with solid flooring) to rest in and then avoid defecating and urinating in this sleeping area (Nannoni et al., 2020; Ocepek et Andersen, 2022).

Partly slatted flooring systems allow pigs to express their thermoregulatory behaviour more easily than fully slatted systems, since they can choose to lie on the slatted floor in hot weather (entailing the risk of defecation on the solid area) and on the solid floor in colder weather (Huynh et al., 2004).

Health

Partly slatted floors generate fewer foot and limb lesions and less lameness. They therefore have welfare advantages over fully slatted floors (Nielsen et al., 2002; KilBride et al., 2009b; Temple et al., 2012). Candotti et al. (2004) suggest that the clinical symptoms of lameness are less severe on a floor that is more than 40% solid than in a fully slatted system.

2.2.2. Disadvantages of partly slatted flooring

Hygiene and comfort

The EFSA Opinion (2022a) recommends that good hygiene should be maintained on the solid floor areas of partly slatted flooring systems. Indeed, some studies conclude that pens and pigs are less clean on partly slatted systems (50% slatted - 50% solid concrete) than on fully slatted concrete floors (Guingand et Granier, 2001; Courboulay et al., 2003). In a partly slatted pen, if temperatures and/or stocking densities are too high, pigs modify their behaviour by excreting in the solid floor area designed for sleeping, rather than in the slatted area intended for elimination. This multifactorial fouling can lead to a decline in animal and pen hygiene.

Expression of behavioural needs

As with fully slatted floors, straw or fodder for rooting are often not provided on partly slatted floors. In such cases, the pigs' exploratory needs are not met and their oral behaviours are redirected towards other pigs. Without the addition of straw, both partly and fully slatted floors increase the risk of tail biting among conspecifics (Moinard et al., 2003).
Fouling also disrupts the pigs' resting behaviour and increases agonistic interactions (Larsen et al., 2018, 2019; Nannoni et al., 2020).

Health

- Wounds and injuries: Compared with a solid floor covered with thick bedding, a partly slatted floor increases the likelihood that leg wounds (osteochondrosis) will develop, causing lameness in fattening pigs (van Grevenhof et al., 2011).

- Ammonia emissions: Research on the impact of partly slatted flooring on ammonia emissions has produced contradictory results. Under the conditions studied by Guingand et Granier (2001), ammonia emissions were higher on partly slatted floors than on fully slatted floors, with the lying area acting as a major source of ammonia if ventilation was not properly managed. This finding appears to contradict those of other authors, who have found that ammonia emissions increased with the proportion of slatted flooring (Aarnink et al., 1996). However, we should bear in mind that the release of ammonia is closely linked to ambient temperature, and that the authors reported different average ambient temperatures across the two study periods (27.5°C in Guingand et Granier (2001) and 23.6°C in Aarnink et al. (1996)). Indeed, Granier et al. (1996) had estimated that a temperature rise from 24 to 28°C at identical ventilation rates would produce a 15% increase in ammonia emissions.

2.2.3. Proportion of solid surfaces to slatted flooring in partly slatted enclosures

According to the EFSA (2022a), it is difficult to determine the optimum percentages of solid and slatted flooring in a partly slatted housing system. Some of the results relating to pen cleanliness and ammonia emissions are contradictory. Spoolder (2002) found that, in pens of 12 to 24 fattening pigs with a surface area per animal of 1 m^2, the pens were dirtier with 60% solid flooring than with 40%. Similarly, Aarnink et al. (1993, 1997, 2001, 2006) (cited in Vermeij et al., 2009), in their studies of pen fouling and ammonia emissions with 50%, 60% and 75% solid floors, correlated dirtier pens with higher proportions of solid flooring. By contrast, Ocepek et Andersen (2022) found that pen cleanliness increased with the proportion of solid floor per animal and with the quantity of litter present on the solid section.
With regard to ammonia emissions, Aarnink et al. (1996) observed that reducing the slatted floor area (and therefore the area of the slurry pit) in pig housing led to a reduction in ammonia emissions from the pit, but increased dirt and emissions from the floor. Ammonia emissions do not depend solely on the slatted surface but also on the ambient temperature, which, when high, increases the incidence of fouling on solid surfaces, with the animals preferring to rest on the slatted surface (Vermeij et al., 2009). At low temperatures, the levels of ammonia emitted by the solid surface of the lying area and an equivalent slatted surface area have been found to be the same, but in summer, without an air cooling system, the lying area has been observed to emit twice as much ammonia as the equivalent slatted surface area (Guingand et Granier, 2001).
The disparities in the above research results are explained by the complexity of the subject. Indeed, these studies set out to assess the influence of multiple factors, including flooring type (proportion of

slatted floor surface, width of openings and slats), animal age and stocking density, ventilation, temperature, and the presence/absence of straw, on a wide range of parameters (comfort, hygiene, expression of behavioural needs, health, environment). This lack of consensus within the scientific community has produced major differences in the proportions of flooring types required by the various EU Member States for partly slatted floors. Council Directive 91/630/EEC, as amended by 2001/88/EC and 2001/93/EC, laying down minimum standards for the protection of pigs, includes requirements for the proportion of solid flooring only for gilts after servicing and pregnant sows (‘at least 0.95 m² per gilt and 1.3 m² per sow [of the total unobstructed floor area] must be of continuous solid floor, of which a maximum of 15% is reserved for drainage openings’, Annex 3, Article 3.2a, European Commission, 2008). However, the Netherlands also requires 40% solid flooring for rearing pigs and piglets, Denmark requires 50% solid flooring for weaners and 33% for rearing pigs, and Germany requires 50% solid flooring for rearing pigs and gilts (Enting et al., 2006, cited in Vermeij et al., 2009).
To determine the optimal ratio of slatted to solid flooring, the EFSA Opinion (2022a) proposed that the minimum surface area of solid floor required for lying comfort (0.77 m^2 per pig weighing 110 kg) should first be determined, and that the surface area of slatted floor required for the expression of activities, feeding/drinking and elimination behaviours should then be worked out from this starting point. This approach would lead to total surface areas per animal that are greater than those currently recommended (a minimum of 1 m^2 per pig weighing more than 110 kg, cf. European Commission (2008), Article 3.1a in Appendix 3).

2.2.4. Straw or fodder on partly slatted floors

Compatibility of partly slatted flooring with straw distribution

On a partly slatted floor, it is easier to provide loose manipulable materials such as chopped straw, peat or sawdust than on a fully slatted floor. Substrate can be provided at ground level on the solid surface, either directly or by means of racks, ensuring that as little material as possible falls into the slurry pit and that the substrate remains available for the animals. Supplied in small quantities ($\leqslant$ 20 g/pig/day), straw can be evacuated using slurry pumps (Munsterhjelm et al., 2009) or other disposal techniques (see Section 2.1.3). Table 1 provides a summary of the available data on the positive effects on pig behaviour to be obtained from differing quantities of straw, and on any problems encountered in slurry evacuation.

Optimum quantity of straw

Although various studies have demonstrated that exploratory behaviour directed towards straw or other manipulable substrates increased with the quantity of substrate provided, while behaviour redirected towards conspecifics decreased (Day et al., 2002; Fraser et al., 1991), few studies have been carried out that specifically address partly slatted flooring.

- for the expression of exploratory behaviour

Jensen et al. (2015) tested the effects of different quantities of straw on the exploratory behaviour of fattening pigs reared on partly slatted floors (1/3 slatted flooring, 1/3 solid flooring, 1/3 drained flooring). They showed that the time animals spent manipulating the straw increased with the quantity of straw supplied up to 250 g/pig/day, beyond which the effect was no longer significant. Similar results were reported by Bodin et al. (2015). Weaners and fattening pigs on partly slatted floors (40% slatted flooring - 60% solid flooring) were given increasing quantities of straw (from 20 up to 300 g/pig/day), distributed from 1 to 4 times per day. The time animals spent manipulating the straw increased, while the time they spent redirecting their behaviours towards conspecifics decreased, as a function of the quantity of straw distributed. The authors calculated that the minimum quantity of straw needed to affect these two parameters was 200 g of straw/pig/day.

Table 1. Results of the principal studies to discuss the quantity of straw (chopped or long) supplied to pigs reared on slatted floors (full or partial), also indicating positive effects on pig behaviour
Where available, information on straw management methods and manure/slurry evacuation systems is also provided.

Flooring type (% solid-% slatted)[1]	Pig category	Type of straw (chopped or long)	Quantity supplied (g/pig/day)[2]	Positive impacts on pig behaviour[3]	Straw management and manure/slurry evacuation [4]	Reference
FS	Fattening pigs	Long straw Rack	64.4	Exploration and manipulation of the straw	Chopper pump => Manual removal of solid supernatant	Courboulay (2006)
FS	Fattening pigs	Chopped straw (4 cm) Rack or feeding container	8.3 (rack) 10.1 (Nourripaille)	Fewer lesions on the ears and tail with a rack	Floating slurry	Courboulay (2019)
FS	Fattening pigs	Long straw Rack	30	Exploration and manipulation of the straw	V-scraper operated 6 to 12 times/day (increased from start to end of fattening)	Caille and Loussouarn (2016)
PS (67%-33%)	Fattening pigs	Long straw (>7 cm) or chopped straw (5-6 cm) Placed on floor (solid area)	100	No effect of straw length on behaviour Fewer pigs with minor shoulder injuries with long straw	Scraper in slurry pit => Manual removal of long straw (but not chopped) blocking the openings	Lahrmann et al. (2015)
PS (73%-27%)	Fattening pigs	Long straw (>7 cm) or chopped straw (1-7 cm) Placed on floor (solid area)	400	Exploration and manipulation of the straw Less tail biting More positive effects with long straw	Enclosure cleaned 3 times a week	Day et al. (2008)
PS (75%-25%)	Fattening pigs	Chopped straw + wood shavings Placed on floor (solid area)	12.5 (including 5g straw)	Fewer tail lesions	Slurry pump Straw changed twice a day	Munsterhjelm et al. (2009)
PS (33%-33% drained-33%)	Fattening pigs	Long straw Placed on floor (solid area)	10 to 500 (OQ= 250)	Exploration and manipulation of the straw	Straw changed once a day Enclosure cleaned twice a week	Jensen et al. (2015)
PS (33%-33% drained-33%)	Fattening pigs	Long straw Placed on floor (solid area)	10 to 1000 (OQ= 387)	Exploration and manipulation of the straw Fewer redirection behaviours congeners	Straw changed once a day Enclosure cleaned twice a week	Pedersen et al. (2014)

Flooring type (%solid-%slatted)[1]	Pig category	Type of straw (chopped or long)	Quantity supplied (g/pig/day)[2]	Positive impacts on pig behaviour[3]	Straw management and manure/slurry evacuation [4]	Reference
PS (70%-30%)	Fattening pigs	Chopped straw (1-10 cm) Placed on floor (solid area)	20 to 300 (OQ= 200)	Exploration and manipulation of the straw Fewer redirected behaviours towards congeners	Slurry pump Straw changed 1 to 4 times a day	Bodin et al. (2015)
PS (78.6%-21.4%)	Fattening pigs	Long straw Rack	86	Exploration and manipulation of the straw Less tail biting	*Information not available*	Van de Weerd et al. (2006)
PS (67%-33%)	Weaners	Chopped straw Placed on floor (solid area)	13.3 + 7 g if an episode of caudophagy	Reduces the development of episodes of tail biting	Slurry pump Straw changed once a day => Manual evacuation of straw blocking openings => Occasional blockage of slurry evacuation pipes	Lahrmann et al. (2018)
PS (50%-50%)	Weaners	Long straw Rack or placed on floor (solid area)	5 (rack) 20 (on the ground, in 2 passes)	Fewer tail lesions	Slurry pump => Occasional blockage of slurry evacuation pipe with 20 g/p/d of straw on the ground	Zonderland et al. (2008)
PS (50%-50%)	Sows in free-range maternity pens	Chopped straw (3.9 cm, 7 cm or 13 cm)	15 kg at farrowing	Nesting behaviour	Scraper in slurry pit => Obstruction of slat openings by longest stalks (13 cm) only (no obstruction with 2 lengths of short stalks)	Westin et al. (2013)

1. FS: fully slatted
PS: partly slatted

2. OQ: optimal quantity for the behaviours observed

3. with either the quantity of straw stated or optimal quantity according to the study

4. => Technical problems noted in the study

- for the prevention of tail biting

To restrict oral manipulation among conspecifics, Pedersen et al. (2014) estimated that the optimal quantity of straw for fattening pigs on partly slatted floors (1/3 slatted floor, 1/3 solid floor, 1/3 drained floor) is around 400 g/pig/day, and that provision of larger quantities has no increased benefits for the prevention of undesirable behaviours. By contrast, when the quantity provided falls below this amount, there is a linear increase in unwanted behaviours as the quantity decreases (from 400 to 10 g/pig/day). Other authors have shown that, for pigs reared on partly slatted floors, the risk of tail biting was significantly reduced when straw was supplied at ground level (10 g/pig/day divided into two deliveries) compared with approximately 5 g of straw/pig/day in a rack or with objects (metal chain, hanging rubber hoses) (Van de Weerd et al., 2006; Zonderland et al., 2008). In another study, conducted on weaned and unweaned piglets and fattening pigs, tail biting was greatly reduced by distributing small quantities of finely chopped straw, to which wood shavings were added (12.5 g/pig/day) on the floor (Munsterhjelm et al., 2009). In addition, this study showed that the incorporation of small quantities of straw into piglets' feed from the maternity stage onwards prevents and reduces aggressive behaviour at later stages of the piglets' development. An even smaller quantity of supplementary chopped straw (7 g/pig/day) has also been tested. This was added to the initial quantity supplied (13.3 g/pig/day) at the first signs of tail biting in weaners on partly slatted floors (1/3 concrete slatted floor, 2/3 solid concrete floor). The additional straw intake significantly reduced the development of further tail biting episodes (Lahrmann et al., 2018).

Most of these studies show that the provision of straw on partly slatted floors, even in small quantities, reduces the incidence of tail biting (Day et al., 2002), at least in production systems with relatively low stocking densities (Wallgren et al., 2019). In its 2022 Opinion, the EFSA considered that tail biting could be reduced by the provision of 20 grams of organic substrate per pig per day on solid flooring, while greater quantities, of up to 400 grams, would have greater effects. However, experts from the pig welfare sub-group of the European Platform for Animal Welfare have drawn attention to the difficulty involved in making a precise standard recommendation on the quantities of enrichment materials that should be provided, as this depends on the farming system and on the age of the pigs. These experts are of the view that in seeking to reduce tail biting, the quantity of straw provided is not as important as the degree to which the pigs actually make use of it. They consider it preferable to supply pigs with small quantities of enrichment materials once or twice a day rather than a large quantity once a week. They conclude that the provision of 400 grams of straw per animal would not be practicable for fattening pigs, where farms can house up to 2000 animals. Attempts to meet such a requirement could also lead to straw shortages in the EU (EU Platform on Animal Welfare, 2023).

In Finland - where tail docking has been banned since 2003, and the majority of farms operate a partly slatted flooring system (D'Eath et al., 2014) – pig farmers are encouraged to use small quantities of straw that are replenished twice a day, and tail biting has been brought under partial control (Valros, 2022).

By 2021, the Finnish certification system, Sikava, covered around 90% of pig farms and 97% of pig production (Valros, 2022). Veterinary checks carried out in 2020 on Sikava farms showed that on 73.5% of these farms, more than 95% of animals had intact tails (with no sign of recent or old bites); on 18.1% of farms, more than 80% of animals had intact tails; on 7.3%, more than 70% of animals had intact tails; and on only 1% did less than 70% of animals have intact tails (Eläinten Hyvinvointikeskus, 2023, p. 276). Moreover, an inspection carried out in a Finnish abattoir in 2019 reported that animals with severe tail wounds represented only 2.5% of carcasses and that those with a maximum tail length (> 24 cm) were in the majority (81.7%) (Valros et al., 2020). Thus, rearing pigs on partly slatted floors with straw, even in small quantities, and good management of the indoor environment, makes it possible to limit tail biting without resorting to tail docking.

- for the cleanliness of pigs and pens

Wallgren et al. (2020) compared the effects of the 'normal' quantity of straw distributed by farmers to fattening pigs on partly slatted floors (control group: from 4.5 to 54.5 g/pig/day depending on the farm and the age of the pigs) with a doubled ration (from 9 to 109 g/pig/day). Very few pens or animals were considered dirty, regardless of the quantity of straw distributed, and no correlation between the quantity of straw and pig and pen hygiene was found, which the authors attributed to the confounding effects of other environmental factors. They concluded that the distribution of straw in the pens of fattening pigs

on partly slatted floors in the quantities practised on the farms studied does not prevent the animals' environment from being kept clean.
According to Westin et al. (2013), it is technically feasible to provide large quantities of straw as nest-building material for loose-housed groups of sows on partly slatted floors around farrowing, provided that the straw is cut. The straw can then be properly drained and the pen kept clean. These authors have also reported that sows in free-range maternity pens on partly slatted floors choose to build their nests on the solid-floored part of the pen (Westin et al. (2013).

2.2.5. Optimisation of housing on partly slatted floors

Enclosure design

To allow pigs to establish a lying area that is separate from the dunging area, it is preferable for the dunging area, and therefore the slatted floor, to be located at the rear of the pen, rather than on the long side of a narrow pen (Larsen et al., 2018). With this layout, the animals and the pen are cleaner and atmospheric ammonia levels are reduced (Ocepek et Andersen, 2022). With regard to pig comfort while resting, experts from the pig welfare subgroup of the EU Platform on Animal Welfare state that 'pigs prefer the solid floor towards the back walls [of the pen], where the area is calmer', while 'for practical reasons, farmers prefer to place the solid flooring towards the between the pens, as it is easier to distribute the straw.' (EU Platform on Animal Welfare, 2023). Partitions can be installed to separate elimination areas from sleeping areas in partly slatted systems. Where this is the case, partitions with openings permit better air circulation, which also helps to reduce ammonia levels (Ocepek et Andersen, 2022) (Figure 7).

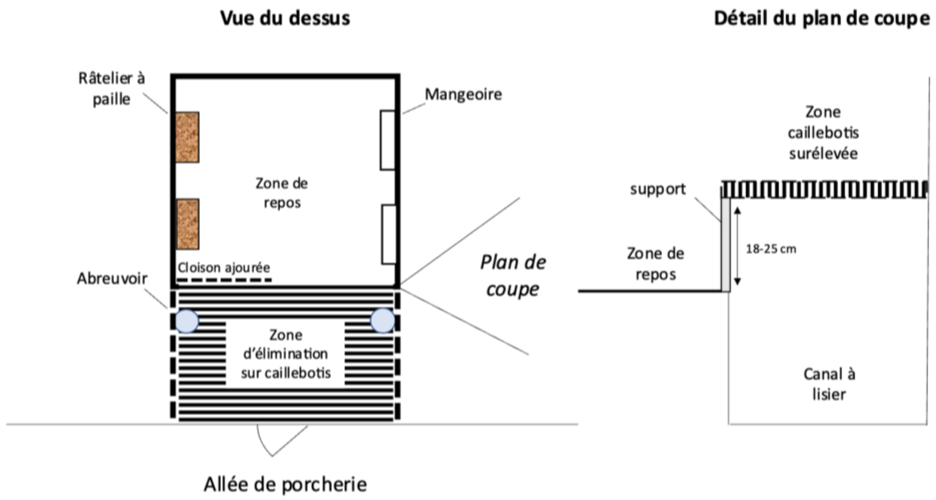

Figure 7. Diagram of a partly slatted fattening pen (60% solid, 40% slatted flooring) optimised for straw distribution

The elimination area with slatted flooring is raised by between 18 and 25 cm for pre-fatteners and finishers respectively (see Götz et al., 1992). A partition with openings separates the resting area from the elimination area. Straw racks are placed in the resting area.

The EFSA Opinion (2022a) makes specific recommendations for sows housed on partly slatted floors in a maternity unit as follows. If, towards the end of pregnancy, sows are housed in individual cages on partly slatted floors, a solid surface must be provided at the front of the stall to enable them to deposit and manipulate nesting materials. These materials must be made accessible in a rack placed at the level of the animal's head and regularly renewed. If gilts and pregnant sows are kept in individual cages on partly slatted floors for the first 4 weeks of gestation, the provision of a substrate on the floor (straw) is recommended.
To restrict the migration of bedding materials from the solid area to the slatted area and avoid blocking the openings between the slats, it is possible to design enclosures that are divided by raised ribs (5.5 cm high, for example (Zwicker et al., 2013)) or to include two levels in the design, with the slatted area raised (Van Putten, 1980). In pens with a raised slatted floor, the slatted floor is raised by 18 - 25 cm (pre-fatteners and finishers respectively) above the solid surface (Götz et al., 1992) (Figure 7).

Control of the building's atmosphere

The recommendations are broadly the same as those in Section 2.1.3 for fully slatted floors. In addition, the European Commission Joint Research Centre (2017, p.367) recommends reducing the surface area of the slatted floor and slurry pit to reduce ammonia emissions. However, ammonia is also released by droppings present in the lying area, especially in hot weather when pigs change their lying behaviour. The lying area should therefore be cleaned regularly to limit ammonia emissions. One study has shown that, during hot periods on partly slatted floors, an increase in air velocity from 0.5 m/s to 1.0 m/s (maximum) in the lying area (achieved by redirecting the inlet air from the ceiling inlets down into the animal zone) encourages pigs to remain in the lying area to rest and to defecate on the slatted floor, thereby reducing fouling problems and cutting ammonia emissions by 21% (Jeppsson et al., 2021).

Use of racks for straw provision

To optimise the use of straw on partly slatted floors without blocking the openings and the drainage system, the use of racks to provide straw to pigs would appear effective (Beattie et al., 2001; Van de Weerd et al., 2006; Zwicker et al., 2012, 2013). The action of pulling at the straw in the rack (positioned over a solid floor) and then manipulating the straw that has fallen to the ground has the advantage of engaging the animals in two activities with the same small quantity of straw (Figure 8).

Figure 8. Gestating sows on a partly slatted floor with straw provided via a rack positioned above the solid area
Credit: Ifip

The type of rack used is important. The bars must be far enough apart for the straw to be accessible, but it must not fall too quickly to the ground (Caille et Loussouarn, 2016) and needs to be at snout height (Figure 9).

In the study conducted by Wallgren et Gunnarson (2022) on a partly slatted floor (25.5% slatted floor and 74.5% solid floor), fattening pigs supplied with straw in high racks (50 cm from the floor) did not use the straw during the first observation period (week 2). Introduction of the racks from post-weaning to teach piglets to direct their exploratory behaviour upwards, together with a lower rack height (the height of the pigs' withers was 44 - 47 cm) could facilitate their use by the pigs. In this study, the exploratory behaviour of pigs was similar whether straw was distributed on the ground (approximately 100 g/pig/day) or accessed via racks filled daily (Wallgren et Gunnarson, 2022).

Figure 9. Basket rack to help fattening pigs grasp hold of the straw
Image from Caille and Loussouarn, 2016

2.2.6. Feasibility of converting a fully slatted building to partial slatting

The implementation of BATs should make it possible to reduce the environmental impact of pig farms. Three main parameters are targeted: ammonia, water consumption and energy consumption. Among the BATs listed (European Commission, 2017), reducing the surface area of the slatted flooring, and with it that of the slurry pit, is proposed as a means to reduce the ammonia released into a building's atmosphere. However, where a fully slatted floor is converted to a partly slatted system by replacing a part of the slatted floor with a solid lying area, if no corresponding modifications are made to the slurry temporary holding system, it has been shown that air quality parameters (ammonia in the atmosphere, ammonia on emission and odours) will be significantly degraded (Guingand, 2003). To reduce the release of ammonia in a partly slatted system, ambient temperatures must be lower than for fully slatted floors, leading to a reduction in feed efficiency and carcass quality and an increase in production costs (Guingand et al., 2010).

Regarding cleanliness and use of space by the animals, one study concluded that converting rooms with fully slatted floors to partly slatted flooring does not improve pig welfare. It reported that, compared with fully slatted flooring systems, animals were dirtier and were unable to establish separate lying, dunging and feeding areas (Courboulay et al., 2003). Converting rooms to a partly slatted system would only be justified if it was accompanied by strategies to enrich the environment (adding straw and manipulable objects to the solid area).

Studies into the costs of converting a building from a fully slatted to a partly slatted system are very rare. In 2001, Gourmelen and his colleagues estimated that conversion from fully to partly slatted floors resulted in an additional fattening cost of 0.18 FRF/kg of carcass due to the expense of building alterations and the increase in surface area per animal.

Box 2. Key points to remember about partly slatted flooring systems

Points to bear in mind when designing the building

- When designing a building, partly slatted floors should be preferred to fully slatted floors, as they promote comfort and resting behaviour.
- In the case of partly slatted flooring systems, there is no consensus in the literature on the optimum proportion of slatted to solid floor. The right balance must be found between the hygiene and cleanliness of the animals and the enclosure on the one hand, and animal comfort, the opportunity to provide sufficient enrichment materials, and a reduction to the risk of tail biting on the other.
- On partly slatted floors, the EFSA recommends that, for comfort, the minimum surface area of the solid-floored lying area should be 0.77 m^2 /pig weighing 110 kg.
- To restrict the quantity of substrate that falls between the slats, the slatted area can be raised.

Opportunities for environmental enrichment

- A partly slatted floor is better suited to the distribution of straw than a fully slatted system.
- As with fully slatted floors, the provision of manipulable materials in partly slatted systems reduces the risk of tail biting.
- A supply of 20 g of straw per pig per day is sufficient to reduce the risk of tail biting in weaners and fattening pigs reared on partly slatted floors, but the benefit increases with the quantity of straw supplied. On partly slatted floors, the maximum effect would appear to be obtained using 400 g/pig/day, but it is possible to reduce tail biting episodes with the addition of even very small quantities of straw (7 g/pig/day).
- Pig exploratory behaviour is satisfied by the provision of 200 g straw/pig/day on a partly slatted floor.
- The cleanliness of the pens and pigs can be maintained by providing a minimum of 4.5 g straw/pig/day on partly slatted floors.
- Chopped straw reduces clogging of the gaps in slatted flooring and of manure evacuation systems, unlike straw supplied as whole stalks.
- The supply of straw in racks positioned above a solid surface enables the pigs to be kept adequately occupied.
- To improve the welfare of peripartum sows, we recommend switching to a cage-free housing system incorporating a solid surface, so that animals can be provided with optimum nesting materials in sufficient quantity.

Control of building atmosphere

- To limit ammonia emissions, we recommend reducing the surface area of slatted floors and the slurry pit, cleaning gutters regularly, and installing effective ventilation.

2.3. Solid flooring

2.3.1. Advantages of solid flooring

Comfort and hygiene

Pigs prefer to lie on solid floors when they are in their thermal comfort zone (Aarnink et al., 1996; Larsen et al., 2018; EFSA Panel on AHAW, 2022a). In particular, it has been shown that pregnant sows with a higher hierarchical rank in the group choose to rest on the solid part of the floor, leaving the slatted areas to the youngest sows and to sows lower down the hierarchy (Horback et al., 2021).

Expression of behavioural needs

A meta-analysis has demonstrated that there are fewer agonistic social interactions between pigs on solid floors than on slatted floors (Averos et al., 2010).

Health

Pigs suffer from fewer foot injuries and less lameness when reared on solid floors than when reared on slatted floors (Fritschen, 1979, cited in EFSA, 2007a; Nielsen et al., 2002; Jørgensen, 2003).

2.3.2. Disadvantages of solid flooring

Comfort and hygiene

On hard, abrasive floors such as concrete, the heaviest animals (fattening pigs, sows, boars) are unable to rest comfortably (EFSA Panel on AHAW, 2022a). Leg injuries such as subcutaneous bursitis and wear on the hocks, which are a source of discomfort, are associated more commonly with lying on hard floors (Mouttotou et al., 1998, 1999; Scott et al., 2006).

If the drainage/cleaning of solid floors is not adequate, manure can accumulate, reducing the ability of the pigs to stay clean (EFSA Panel on AHAW, 2022a). In fact, animals are often dirtier when reared on solid floors compared with slatted floors (Guingand et Granier, 2001). Floor hygiene is more difficult to maintain in pens with fully or partly solid floors, and calls for frequent slurry scraping compared to fully slatted floors.

Health

On solid floors that have been made slippery, by the presence of excrement in particular, large animals reared in groups are likely to slip and fall during agonistic interactions, as are sows displaying mounting behaviour during oestrus. For example, gilts and sows display more lameness and impaired gaits when reared on wet, dirty (slippery) solid floors than on smooth, dry, clean solid floors (Wachenfelt et al., 2008).

Where litter is not provided, the floor material itself will affect the risk of foot injuries. For example, concrete floors that are in poor condition or overly abrasive are more likely to cause foot injuries (such as calluses, Leeb et al., 2001) than a smooth concrete floor (Brennan et Aherne, 1987; EFSA Panel on AHAW, 2022a), and this can lead to locomotive problems (KilBride et al., 2009b).

The EFSA Opinion (2022a) indicates that gastrointestinal disorders are more frequent on solid flooring, particularly when the removal of fecal matter is infrequent or inadequate.

2.3.3. Optimisation of accommodation on solid flooring without bedding

To maintain floor hygiene, the EFSA Opinion (2022a) recommends preventive management practices, involving effective drainage, an adequate floor cleaning plan, pen design that encourages the use of different functional areas and regular floor cleaning, which can be done mechanically using a scraper.

Machine smoothing of initially rough concrete floors, application of resin or rubber paint to concrete floors (Brennan et Aherne, 1987) or the use of a synthetic floor material that deadens or reduces friction (Phillips et Pawluczuk, 1995; Phillips et al., 1995; Gu et al., 2010) could be considered as ways to limit the abrasiveness of solid flooring (including the solid area in partly slatted systems), particularly for unweaned piglets whose skin and feet are soft and vulnerable (Kirkden et al., 2013). Newly poured concrete or latex floors cause fewer severe stifle lesions in unweaned piglets than older concrete floors (Kirkden et al., 2013).

Adding mats to the sleeping area can reduce foot injuries. Mats can be made of plastic (with a smooth or open structure non-slip surface) or rubber. One study has shown that the use of mats in the resting area of fattening pigs, particularly soft plastic mats with a smooth surface, resulted in fewer limb injuries than bare concrete floors or even floors covered with a thin layer of bedding (Savary et al., 2008).

In farrowing pens, rubber lying mats reduce the incidence of bursitis in sows (Díaz et al., 2013) and leg lesions in fattening pigs (Falke et al., 2018). Similarly, a neoprene mat placed under the sow and in the piglet suckling area reduces piglet leg injuries, increases sow comfort and reduces the incidence of deaths by crushing (Gu et al., 2010). When given a choice, group-housed sows prefer to lie on a rubber mat than on a bare solid floor (Tuyttens, 2005). To avoid the risk of injury, solid floors should therefore be made of smooth (non-abrasive) materials with non-slip properties or covered by mats (Baxter et al., 2011), and should be regularly scrubbed.

Box 3. Key points to remember about solid flooring without litter

- In a thermoneutral zone, a solid floor is more comfortable for pigs to rest on than a slatted floor.
- In piglets, solid floors reduce the risk of foot lesions.
- To avoid the risk of injury, solid floors must be regularly cleaned, constructed of smooth materials with anti-slip properties and in good condition, or covered with a mat.

2.4. Solid flooring with scraped litter

2.4.1. Advantages of solid flooring with scraped litter

The main advantage of a solid floor over a slatted floor is that it allows provision of a greater quantity of manipulable substrate, with widely demonstrated beneficial effects on pig welfare (see Sections 1.4.3 and 1.4.4, EFSA Panel on AHAW, 2022a; CNR BEA, 2024). On solid flooring, litter is provided on the floor of the lying area, while feeding and elimination areas are kept bare. This sort of system is known as a scraped or Straw-Flow system.

According to the literature, the effects of the presence of straw on pigs' leg quality and behaviour are variable and findings can even be contradictory, probably due to differences in the quantity of straw supplied.

Comfort and hygiene

The living areas in the pens are clearly demarcated, particularly by the presence of bedding in the sleeping area, which reduces the risk of fouling.

Under thermo-neutral conditions, pigs prefer to lie on straw-covered floors rather than directly on rough surfaces, but this preference depends on the ambient temperature – straw is chosen at low temperatures whereas rough floors are chosen at higher temperatures (Fraser, 1985).

If a deep layer of straw is provided, the animals suffer less from bursitis in their leg joints (EFSA Panel on AHAW, 2012), a complaint that causes discomfort and disrupts rest.

Expression of behavioural needs

The risk of tail biting, which arises when pigs' behavioural needs for manipulation and foraging are not met, is reduced when pigs are reared on solid floors with bedding. Indeed, Madsen (1980) (quoted in (EFSA Panel on AHAW, 2007a)) found that the proportion of tail-biting pigs was 29% when the floor was fully slatted, 16% when the floor was partly slatted, and 2% on solid flooring with scraped bedding. Post-weaners and fattening pigs reared on solid floors with litter had fewer negative interactions with their fellows and displayed more play behaviours than those reared on bare partly slatted floors (Hötzel et al., 2009). Piglets weaned at three weeks displayed less oral behaviour redirected towards conspecifics in straw flow systems compared with piglets housed on expanded metal slatted floors (Kelly et al., 2000). Thus, negative social behaviour, but also positive behaviour, is generally less present on litter than on slatted floors (Courboulay et al., 2008, 2009). This may also be linked to the level of crowding among conspecifics in slatted floor systems, where the density of animals is often higher.

A British epidemiological study has shown that rearing on scraped litter was more likely to stimulate exploration behaviour in pigs, thereby reducing the risk of redirected behaviour and tail biting, compared with a deep litter system (Hunter et al., 2001). According to the authors, a regular supply of small quantities of fresh straw is more attractive to pigs than a deep litter system where straw is constantly available, but less frequently renewed and more contaminated by excrement (Hunter et al., 2001).

Health

Straw bedding provides a better grip on the ground and reduces the risk of heavier animals falling. Thus, for group-housed gestating sows, provision of straw bedding in any quantity reduces the risk of falling in the event of a fight, explaining the reduced injuries and lameness compared with a bare solid floor (Andersen et al., 1999; Barnett et al., 2001).

2.4.2. Disadvantages of solid flooring with scraped bedding

Expression of behavioural needs

Providing litter in small quantities on a solid floor does not achieve the same reduction in tail biting and aggressive behaviour as a deep litter system in fattening pigs (KilBride et al., 2009b).

Health

If straw is distributed in small quantities (scattered or thin litter), the risk of lameness and bursitis is greater than with deep litter in fattening pigs (KilBride et al., 2009b).
If straw is damp, the mycotoxins produced by mould may affect the health of the animals (immunosuppressive effect and causing respiratory and digestive diseases) (EFSA Panel on AHAW, 2022a).

2.4.3. Focus on sows in the maternity area

A study has reported that pregnant sows housed in groups in an enriched environment (solid floor, 50% concrete, 50% sand, straw rack) displayed nesting behaviours similar in every respect to that of sows kept in the open air as follows. 24 hours before farrowing, they rooted and dug into the sand to form a hollow surrounded by a rim of sand. They then transported large quantities of straw (23 kg on average per sow) into the hollow and around its edges, moving and manipulating the straw with their legs and snouts (Arey et al., 1991).
A layer of sand on a solid concrete floor combined with a straw rack improves the comfort (fewer changes in posture) and maternal behaviour (fewer piglets crushed, better recognition and response to distress vocalisations from their young, longer suckling times) of lactating sows compared with sows reared on a solid floor without litter or a rack (Herskin et al., 1999).
In pregnant and lactating sows, cases of bursitis are reduced on both deep bedding and smaller quantities of material (Munsterhjelm et al., 2015).

Box 4. Key points to remember about solid flooring with scraped litter

- A solid floor with scraped litter is more comfortable to lie on, stimulates more exploratory behaviour in pigs and nesting behaviour in sows, and greatly reduces negative behaviour towards other pigs (including tail biting) than a fully slatted floor.
- Although the positive effects on pig welfare increase with the quantity of straw, there is a lack of scientific data to determine the optimum quantity of straw that should be provided in systems with scraped litter.
- The majority of studies conclude that the presence of litter, even a scattering, reduces leg lesions. The presence of dry litter also helps pigs to grip a smooth surface with their feet and reduces the risk of falling for large, group-housed animals.

2.5. Deep litter

2.5.1. Advantages of deep litter

Comfort and hygiene

In a deep litter system, the entire surface occupied by the animal is kept clean and dry by the regular addition of absorbent bedding material.
In order to maintain the hygiene of a deep litter system, the number of pigs per square metre must be lower than in other systems, giving the pigs more space compared with fully or partly slatted flooring systems (EFSA Panel on AHAW, 2007b).
At low ambient temperatures, the presence of deep bedding provides thermal comfort for the animals (EFSA Panel on AHAW, 2022a). Pigs can choose to lie in the most thermally comfortable area and relieve themselves in one or more cooler, wetter areas of the pen. During cold spells, thermal comfort is improved because dry, well-maintained bedding heats up. Conversely, pigs may prefer to lie in wetter areas in hot weather.
It has been shown that it takes pregnant sows half the time to move from standing to lying on litter compared with slatted floors, suggesting greater comfort and better physical soundness on litter (Salaün et al., 2002). Similarly, the risk of bursitis in fattening pigs decreases with flooring type (Mouttotou et al., 1998, 1999). The authors rank the flooring types by risk level as follows (from high to low): fully slatted floor, partly slatted floor, scattered straw on a solid floor (< 10 cm) and deep litter (> 10 cm), this last producing the best results.

Expression of behavioural needs

In farm buildings, deep litter systems provide a manipulable substrate and do not necessarily require further materials to be added (Anses, 2015). Pigs are extremely active animals who are reported to take a strong interest in their litter, expressing investigative behaviour (Courboulay et al., 2009) or, in the case of piglets, playing and chewing behaviours (Tuyttens, 2005). This activity helps the litter to function properly by improving its porosity, enabling the necessary aerobic fermentation to take place (Chambres d'agriculture de Bretagne et al., 2012).

A recent study has shown that gestating sows displayed more investigative and rooting behaviours when kept on deep litter rather than fully slatted floors, whether other enrichment materials were present or not (Merlot et al. 2022). During the maternity phase, all the sows in the trial were then housed on slatted floors. Piglet survival in the first 12 hours was better for the sows who had spent their gestation on litter. Additionally, these sows interrupted lactation sequences less frequently at the start of lactation than did sows who had been housed on slatted floors without enrichment materials during gestation, which the authors linked to a better level of welfare for the sows during gestation (Merlot et al. 2022).
Piglets weaned at three weeks have shown less oral behaviour redirected towards conspecifics in deep litter systems in comparison to piglets housed on expanded metal slats (Kelly et al., 2000).
A review of the literature estimates that pigs reared on bedding display more positive social interactions and fewer aggressive or undesirable behaviours (belly-nosing) with increased litter depths compared with a small quantity of straw (Tuyttens, 2005). Evidence of tail-biting problems becomes only anecdotal in the presence of deep litter (Fraser et al., 1991; Ramonet et Villain, 2021), with potential positive economic impacts on pig production (Van Staaveren et al., 2021).

Health

One study has reported that fattening pigs had significantly fewer carpal and tarsal lesions in deep litter systems than on partly or fully slatted floors (EFSA Panel on AHAW, 2005). In deep litter systems, there is no risk of the animals slipping on the concrete floor as this is always covered with litter.

2.5.2. Disadvantages of deep litter

Comfort

In summer, when litter ferments more and produces a large quantity of heat, pigs can suffer from thermoregulatory problems and become heat-stressed (EFSA Panel on AHAW, 2007b).

Expression of behavioural needs

In growing and fattening pigs, Morrison et al. (2007) observed that an increase in investigative and manipulative behaviours stimulated by the materials furnished by a deep litter system led to a reduction in positive social interactions between the pigs. However, these results contradict those of Tuyttens (2005), which showed increased positive social behaviours on deep litter.

Health

The provision of straw, particularly of poor quality, and use of wood shavings and sawdust increase the production of airborne particles such as dust, moulds and fungi associated with respiratory disorders in pigs and humans (Boon et Wray, 1989; EFSA Panel on AHAW, 2007b).
A further disadvantage of the deep litter system is that it increases gas emissions, including ammonia (which has a negative impact on a building’s atmosphere), nitrous oxide and methane (both of the latter being greenhouse gases) (Chambre d’agriculture de Bretagne et al., 2012; EFSA Panel on AHAW, 2007b).
Similarly, if the processes by which litter is broken down are not properly managed, viral agents (Ewald et al., 1994), bacterial agents (Skjerve et al., 1998) and parasites (Roepstorff et Jorsal, 1990) (cited in Tuyttens, 2005). can accumulate in deep litter.

2.5.3. Deep litter management to promote pig welfare

When designing a pig-rearing unit where straw is regularly added, an important point to consider is ease of operation for the supply and spreading of additional straw and cleaning in the presence of the animals (building heights allowing clearance for machinery/tractors, corridor widths, partition heights, storage areas, etc.) (Chambre d'agriculture de Bretagne et al., 2012).

In a deep litter system, straw is introduced in very large quantities at the start of each phase (between 20 and 25 kg per pig) (Welfarm, 2015). The straw should be topped up every 7 to 10 days, prioritising the areas where droppings are found. Pens should be cleaned and disinfected only once the animals have left.

The moisture content and porosity of the litter are both essential parameters for good deep litter management. Encouraging the evaporation of moisture and limiting emissions helps to keep the bedding dry (and therefore comfortable for the pigs) and sanitary (no build-up of pathogens). Insulation of the floor and walls of the building and provision of ventilation are therefore essential, not least to avoid heat loss in winter. If evaporation rates from the litter are reduced by cold, wet weather, more frequent addition of materials will help to keep the litter dry. One study compared five deep litter materials supplied to breeding boars (two types of wood shavings, hemp straw, flax straw, spelt husks) and assessed their respective impacts on litter temperature, pen cleanliness (in winter), and fly load (in summer). The authors recommended the use of wooden materials for deep litter, these being less prone to heat build-up, and that litter replacement should be avoided during the warmer months (Riedel et al., 2024). The EFSA Opinion (2022a) recommends that animals be given access to an alternative type of floor in the event of heatwaves. For systems using wood shavings (sawdust), the initial layer at the start of the phase must be sufficiently thick (no less than 15-20 cm) due to the high absorbency of this material.

For weaners and fattening pigs, the height of the feeding area must initially be 40 to 50 cm above the straw-bedded area, as the latter area can reach this height by the end of the phase. A raised step is essential for piglets to be able to access the feed troughs easily at the start of the phase. Similarly, the corridors used to move the animals must be raised above the bedding area so that, at the end of a phase, the corridor will be at the same level as the bedding and the pigs can easily access the exit corridor (Chambre d'agriculture de Bretagne et al., 2012).

Box 5. Key points to remember about deep litter

- Deep litter allows maximum expression of pigs' investigative behaviour and provides them with a good level of comfort.
- On deep litter, the risk of tail biting is minimal.
- In hot weather, pigs reared on deep litter can experience heat stress. It is therefore essential for the barn to be well insulated and ventilated.
- Deep litter can affect ambient air quality: it emits various gases, including ammonia, and releases airborne particles, which can cause respiratory and eye problems in the animals. Good ventilation of the building is therefore essential.
- The risk of greenhouse gas emissions may be higher on deep litter.
- The management of deep litter is more technical than that of slatted flooring systems and therefore requires greater supervision on the part of the farmer.

2.6. Obstacles and levers for the development of alternatives to fully slatted flooring

The alternatives to fully slatted flooring that are designed to meet the behavioural needs of pigs can be summarised and ranked from lowest to highest in terms of their positive impact on pig welfare as follows:

1. Partly slatted flooring system: separate solid and slatted areas for easy demarcation of different functions. Pigs are provided with objects that can be manipulated and deformed (pieces of wood, rubber hoses or ropes) fixed to the wall or floor.

2. Partly slatted flooring system with straw: partly slatted flooring system with small quantities of straw distributed using racks or scattered (preferably in chopped form to assist waste removal) across the solid lying area. Manipulable objects are provided.
3. Scraped litter system: solid floor with the addition of litter (preferably long-stemmed straw) to the lying area. Routine replenishment of litter and scraping are necessary.
4. Deep litter system: solid floor entirely covered with a large quantity litter (preferably long-stemmed straw) that builds up over time. Routine addition of materials is necessary.

In November 2019, only 5% of French pig farms used scraped or deep litter systems (RMT Elevage et Environnement, 2019). Despite their positive impact on animal welfare, these systems are not part of mainstream farming in France due to a certain number of obstacles.

The implementation of alternatives to fully slatted flooring systems faces various barriers in France. These relate mainly to straw provision, which can be the stumbling block for some farmers. Levers for action are, however, available to set up these farming systems. In this section, we examine the various obstacles to the introduction of the three main alternative systems that call for the provision of loose substrate to improve pig welfare (partly slatted with straw, scraped litter and deep litter systems), along with possible levers for action.

2.6.1. Obstacles

Economic constraints

The available data mainly relate to straw-based systems.

- Infrastructure development costs: the buildings and equipment needed for straw-based systems require alterations to be made to building construction, layout and management. Changes include: concreting floors and increasing the surface area per animal compared with slatted systems; laying out corridors and pens and installing barriers; changing the waste removal system to allow litter to be scraped, rather than using gutters or a pit below a slatted floor; storing manure in a composting pit rather than a slurry pit below a slatted floor. Advance consideration must be given to the design of buildings to facilitate work flows, particularly where straw handling is mechanised (ceiling heights and aisle widths must be compatible with the passage of machinery). Rousseliere (2024) calculated the comparative costs of building construction and of the space allocated to each animal (taking into account the cost of construction only, not of farming inputs and labour) for fattening pigs reared using straw-based and slatted flooring systems in 2023. The costs per allocated space for a fattening pig were €757 on straw compared with €583 on slatted floors, i.e. an additional cost of 30%, which was attributed to the higher construction standards and technical sophistication of buildings for straw-based systems.

- Operating costs:
    - Input costs: straw purchase (if not home-produced) and management constitute additional costs compared to fully slatted systems (D'Eath et al., 2014).
    - Feed costs: poorer feed conversion and a higher feed consumption rate for animals on litter (linked to higher energy expenditure in physical activity and thermoregulation) means that feed costs are higher (Giorgetti et Robin, 2008; Chambre d'agriculture de Bretagne et al., 2012).
    - Additional labour costs: straw handling (distribution, scraping) and the cleaning of buildings may require more labour (Bornett et al., 2003).

- Farm profitability:
    - Lower stocking density: more space per pig is required to keep the manure inside the pen, establish separate functional areas for dunging and lying, and ensure efficient evaporation within the straw bedding, than in slatted flooring systems.
    - Overall additional cost per animal leaving the farm: a 2008 study estimated this to be an additional €3 per pig reared on straw compared with slatted flooring (Giorgetti and Robin, 2008). This would be €3.95 in 2024 (applying average inflation rates to all item costs, i.e., investment, consumables, labour).

Technical obstacles

- Supply of quality bedding: if straw is used, this can compete with other uses for straw (e.g. in biofuels), potentially causing supply issues, depending on the year and quality of the harvest. This is true for all supply routes (home-grown, external or mixed) (European Commission Joint Research Centre, 2017). Straw quality must be guaranteed and depends, among other things, on harvesting and storage methods. The quantity of straw required varies throughout the year, and is greater in winter.

- Waste elimination systems: in a mixed system combining partly slatted flooring with straw, the management and evacuation of slurry in the pit calls for specialised techniques (floating slurry) or equipment (slurry pumps with chopping blades, etc.), even if the quantity of straw distributed is small.

- Productivity and zootechnical performance: pig growth and feed conversion performance are lower on litter than on slatted floors (Chambre d'agriculture de Bretagne et al., 2012). The carcasses of fattening pigs raised on litter tend to be fattier than those of pigs raised on slatted floors (Paboeuf et al., 2009). This can lead to carcasses being downgraded at the abattoir. Pig growth requires closer monitoring on litter than on slatted floors, so that the fat composition of the carcasses and the muscle content of the cuts can be adjusted through changes to the feed and rationing plan (Chambre d'agriculture de Bretagne et al., 2012).

- Management complexity: the management of litter-based systems can be more complex, requiring increased monitoring and specific skills. For deep litter systems, this includes regular monitoring of changes in the condition of the bedding (especially at the start of the phase) to achieve optimal aerobic fermentation, and of the *in situ* composting of the litter to avoid increases in litter temperature and ammonia emissions (European Commission Joint Research Centre, 2017). Monitoring of the body condition of fattening pigs, and temperature management (including ventilation control), are also needed.

- Workplace ergonomics:
    - Time spent working: certain tasks in alternative systems are time-consuming. For example, litter management requires regular scraping and replenishment in systems with scraped litter, and cleaning and disinfecting of the pens at the end of each phase in deep litter systems (cf. Table 1). Further more time-consuming tasks are the feeding and sorting of the animals. A study by Giorgetti and Robin (2008) has shown that the time spent working per pig was 50% higher for fatteners on straw rather than slatted flooring.
    - Demanding work: straw replenishment and animal sorting are both considered to be particularly labour-intensive in alternative systems.
    - Working environment: the handling of straw (especially of poor quality), wood shavings and sawdust can emit airborne particles, including dust, mould and fungi, that can cause respiratory problems in both humans and animals (EFSA Panel on AHAW, 2007a).

- Health risks: pathogen management can be more complex in litter-based systems, requiring rigorous monitoring and health measures. This is particularly true for post-weaners, who are more vulnerable to pathogens.

- Continued lack of experience with alternative systems: since the number of farms using litter-based systems is small, general principles of good husbandry cannot be established and farmers still find it difficult to compare their own circumstances with those on other farms. This difficulty is compounded by the fact that scientific and technical publications on the subject sometimes produce contradictory results, as the experimental conditions are often not comparable.

Environmental obstacles

- Gas emissions: litter-based systems result in higher greenhouse gas emissions (especially nitrous oxide and ammonia), than do fully slatted systems, and this requires particular management strategies. Lagadec et al. (2013) estimated that 72% of the nitrogen in manure is released into the atmosphere where sawdust bedding is used and 57% with straw bedding. This is mostly in the form of ammonia, which degrades air quality and contributes to eutrophication. Ammonia emissions vary greatly over time and are hard to predict, although we know that they increase with the length of the rearing phase, having been observed to be higher at the end (Giorgetti and Robin, 2008).

- Straw consumption: to provide straw for pig farming, more cereal crops are needed, and therefore more farmland.

Societal barriers

- Resistance to change: for as long as the majority of livestock farms in France still operate on slatted floors, switching to an alternative system may be perceived by peers as a challenge to, or even an attack on, the prevailing system. Furthermore, the relative lack of retrospective data on the real, long-term benefits of alternative systems may lead farmers to overestimate the risks and underestimate the benefits, discouraging them from embarking on a change of system. For example, Taylor et al. (2023) surveyed farmers on the barriers to their use of enrichment, and identified lack of knowledge of the real effects of enrichment on animal welfare as the second most cited reason, with financial cost being the first.

2.6.2. Levers

Economic leverage

- Adding value to animals:
    - The positive impact of deep litter on the physical integrity of pigs, in particular the low proportion of animals suffering from tail biting, means that these can achieve higher values with less risk of seizure at the abattoir on the grounds of very serious tail lesions, limiting losses for the farmer (Harley et al., 2012). Sales losses on these grounds were estimated to be €3.60 per carcass in 2018 (Courboulay and Drouet, 2018).
    - The integration of litter-based livestock farming into alternative valorisation routes for products (labelling, short distribution chains, etc.) offers the prospect of higher selling prices. For some farmers, these provide essential compensation for higher farming costs (Welfarm, 2015).

- Adding value to manure: the manure produced by straw-fed livestock has a high agronomic value, greater than that of slurry. The manure can be used directly by farmers to spread on whatever crops they have (achieving input savings at a time when fertiliser prices are rising sharply), sold to market gardeners, or provided to cereal growers in exchange for straw (Giorgetti and Robin, 2008; Welfarm, 2015).

- Reductions in some operating costs:
    - Veterinary costs are lower than for fully slatted systems – the bedding materials improve animal comfort and hygiene and reduce agonistic social behaviours, while pigs suffer fewer injuries and are less stressed than pigs reared on slatted flooring.
    - Effective use of bedding to reduce tail biting can have a positive impact on feed costs. For example, one study reported that on farms where the occurrence of severe tail lesions was greater than 0.86%, this was accompanied by a 4.8% reduction in average daily weight gain. This increased the time taken to reach the target slaughter weight by seven days compared with farms with fewer tail lesions, resulting in 1.5% higher feed costs and a 15.1% reduction in average annual profit (Van Staaveren et al., 2021).
    - Energy costs for straw-based systems are significantly lower than for slatted systems. Indeed, on slatted floors, 80% of energy costs are associated with mechanical ventilation, while rearing on litter in naturally ventilated buildings can considerably reduce the energy consumption of a finishing unit (-90%) (Giorgetti and Robin, 2008). This 2008 study also estimated that the absence of the need for slurry treatment would reduce overall production costs by €10/pig (i.e., €13.15 in 2024 allowing for inflation) (Giorgetti and Robin, 2008).

- Possibility of financial support from public authorities: some local authorities have provided grants to farmers seeking to switch to straw-based systems (Giorgetti and Robin, 2008; Welfarm, 2015). Such initiatives could be rolled out to national level: either through subsidies and financial help for investment in the infrastructure and equipment needed to set up alternative systems, or through tax incentives for farmers who adopt more sustainable practices that respect animal welfare.

Technical levers

- To improve ergonomics and ease of operation:

  - Some farmers decide to switch to an alternative rearing system to remove the need for slurry management on their farms. Properly managed, deep litter systems generate fewer odours and create a better working environment, which can also have a positive impact on a farmer's health.
  - In a mixed system (partly slatted floor with litter), use of chopped straw prevents the slatted floor slots from becoming blocked.
  - The automation/mechanisation of certain tasks can make these less time-consuming and onerous, e.g. mechanised straw handling and scraping, and automated feed distribution.
  - Leaving straw unspread before the animals arrive saves labour time and helps pigs to integrate better with each other (pigs on litter).
  - Since pigs are reared on litter, tail biting is considerably reduced, eliminating the need for routine tail docking of piglets. This saves time.

- Taking advantage of building conversion: to reduce the technical problems associated with litter-based systems listed in Section 2.5.2, the choice of indoor equipment and of techniques for litter management and the sorting of animals to reduce time spent working all need to be taken into account at the building design stage. By concreting in slurry pits and removing partitions, old buildings with fully slatted floors can be converted for deep litter systems.

- Building on research and development, sharing outcomes and disseminating success stories: a number of research programmes are looking at the design and management of alternative farming systems, including, in France, the GOPEI Occitanie project, the Bâtiment Porcin 2022 project, the Casdar BâtiPorc C4E project, the LIT OUESTEREL project for the co-design of pig housing with high animal health and welfare value, and RMT BATICE. At European level, the WelFarmers project, which began in 2024, aims to improve pig welfare by identifying and sharing best practice among farmers in the various participating Member States. One of its 4 research axes concerns the allocation of space per animal and flooring.
Widespread dissemination of the results of this research could help overcome the reluctance felt by some farmers, particularly in the form of the communication of good practices identified at experimental centres (Ramonet et al., 2015; Ramonet et Villain, 2021) and on working farms (run by peers). Farm visits could be organised to enable direct discussion among farmers.

- Training for agricultural advisors and farmers (current and future): organising training courses on best management practices for litter-based systems would make it possible to disseminate the results of research and development.
A change in farming practices to improve pig welfare could easily appeal to future operators in the sector. Increased teaching on alternatives to fully slatted flooring systems in agricultural colleges and higher education establishments would encourage this change.

Environmental levers

- Management of litter: use of straw can reduce ammonia emissions if it is properly managed, i.e. kept dry (European Commission Joint Research Centre, 2017). Ammonia emission rates are closely linked to litter and manure management, which thus constitutes a lever for improvement (Ruckli et al., 2024).

- Effluent management:

  - Effluent recovery: used litter can be recovered to provide organic compost for crops, creating an opportunity to recycle nutrients. Applied in this form, nitrogen is less likely to leach into the ground and the manure or litter-based compost contains organic matter that increases the humus in the soil, a characteristic of particular interest in Brittany, where soil impoverishment is a growing problem (Giorgetti and Robin, 2008). Humus enrichment improves the soil biome and structure, increases water retention capacity, reduces nitrate and pesticide leaching and improves yields. Conversely, the continued use of liquid manure to fertilise soils results in a lack of organic matter and the reduction, or even disappearance, of organisms in the soil (Giorgetti et Robin, 2008).
  - Water pollution and the emission of noxious odours are reduced in deep litter farm systems.

Societal levers

- Ethics and the societal acceptability of pig farming: alternative systems may be perceived more favourably by consumers with an interest in respect for the environment and animal welfare (by allowing the expression of foraging, exploratory and nesting behaviours, reducing animal boredom and stress, agonistic interactions and tail biting).

This gives livestock farming and the farming profession a better image and greater acceptability. Initiatives such as visits to farms that have switched to alternative systems have been reported, both spontaneous (from local residents) and organised (by professional groups or suppliers) (Giorgetti and Robin, 2008).

- Farmer satisfaction: 'In general, farmers are satisfied with their buildings [after switching to litter systems]. When they raise pigs on litter, unless there are technical or construction problems, they appreciate the atmosphere in the building and the fact that they have natural light to work in. They notice that their animals are more active than on slatted flooring' (Giorgetti and Robin, 2008).

FRCAW conclusions and recommendations

Table 2 and Table 3 provide summaries of the main advantages and disadvantages of each flooring system discussed in this report with regard to pig welfare, considered from the animals' point of view.

To sum up, the alternatives to fully slatted flooring are partly slatted systems (preferably with added straw), or solid floors (with scraped litter or deep litter). These alternatives require better management of the building atmosphere (ventilation) and a larger available surface area in order to control:
- the cleanliness of the animals and their accommodation,
- thermal comfort in hot weather,
- risk levels for infectious diseases.

Alternatives to fully slatted flooring systems can be more effective in achieving:
- the expression of the exploratory and nesting behaviours natural to pigs,
- reduced risk of tail biting,
- sleeping comfort and thermal comfort,
- the possibility of establishing separate functional areas, due to the greater space available,
- reduced incidence of leg lesions, injuries and lameness.

The positive impacts on these welfare criteria increase incrementally (fully slatted flooring < partly slatted flooring < solid flooring < deep litter) in relation to the quantity of straw supplied.

Very few studies exist comparing the animal welfare impacts of partly slatted flooring without straw or solid flooring without straw with fully slatted flooring or with solid flooring with straw, respectively. The use of partly slatted floors or solid flooring would appear to be accompanied by straw provision in most cases.

Indeed, in light of the scientific findings, we can assert that the provision of a manipulable substrate, preferably straw, is the most effective means of enrichment to improve the welfare of pigs housed indoors at all stages of development. Preference should be given to floor types that are compatible with the distribution of straw, and therefore fully slatted floors should be avoided when constructing new buildings or renovating old ones.

However, it is not always feasible for farmers to change floor type in the short term. The reasons for this are mainly technical and economic, and can act as a brake. It should be remembered that fully slatted floors remain the most common type of flooring found in France today.

The literature review reveals that opportunities are available to improve pig welfare for all floor types (see Table 4). In accordance with Directive 2008/120/EC (European Commission, 2008), to improve animal welfare and reduce the need for systematic tail docking, preventive measures adapted to the type(s) of flooring currently installed on farm should be implemented. In addition to the provision of manipulable materials (mainly straw), a number of core factors should be taken into account to prevent tail biting: available space, make-up of social groups, building atmosphere control (thermal comfort and air quality: provision of warmth post-weaning, ventilation, absence of draughts) and adequate feed (De Briyne et al., 2018). Depending on the type of flooring, some of these factors are more critical than others.

Some European countries (Finland, Sweden, Lithuania) have an outright ban on tail docking, achieving limited levels of tail-biting on most farms without excluding the use of partly slatted floors (Valros, 2022). It would be interesting to compare the measures recommended by these countries, their implementation on the ground, and their impacts on reducing tail biting and pig welfare.

Numerous studies have concluded that benefits for pig welfare increase with the quantity of straw provided. Although some results are contradictory, the current recommended range is from 20 to 400 g/pig/day for post-weaners and fattening pigs, where provision of the smallest quantity produces significant results relating to exploration and reduced tail biting, and 400 g achieves the greatest effects. However, the optimal quantities of straw for the different developmental stages have yet to be determined.

This difficulty stems in particular from the fact that experimental conditions are not comparable between studies, and from the chance of the presence of confounding effects within individual studies. The addition of manipulable materials is often combined with other factors such as increased living space and social enrichment (e.g., mixing of litters in the maternity area). This means that the optimal quantity of straw must be dictated by individual farming conditions. Farmers should take stock of their own circumstances: 1) checking whether the straw is being used by the pigs; 2) assessing whether the quantity distributed is appropriate (presence of leftover straw in the rack or on the ground or no wasted straw); and 3) optimising other husbandry practices that affect welfare and the risk of tail biting. There is no standard system, as farmers can adapt the management of their straw bedding to suit their constraints. For example, some farmers choose to house their weaners (who are more vulnerable to health problems) on slatted floors before moving them onto straw for fattening.

Similarly, studies on the effects of floor type on pig behaviour and the risk of tail biting are numerous but rarely comparable. In a number of studies, it is difficult to separate the impact of floor type from the addition of manipulable materials or other factors influencing animal behaviour.

Further research in controlled environments is therefore needed to determine the specific effects of floor type and/or enrichment materials on pig behaviour and tail biting. Such studies should also take into account particular factors that are essential for pig welfare, such as the ambient conditions in the pens (light, temperature, air quality, noise level, etc.). This would generate recommendations for the optimisation of pig welfare on each alternative floor type compared with fully slatted flooring.

Last, this review stresses the importance of socio-economic and environmental factors. Table 2 and Table 3 adopt a One Welfare approach in summarising the advantages and disadvantages of the different types of flooring for farmers and the environment. The obstacles and levers associated with the development of alternatives to slatted floors, summarised in Table 5, are fundamentally linked to such socio-economic and environmental issues. To overcome the reservations of some farmers over the profitability and technical feasibility of switching to an alternative system to fully slatted flooring, the list of main levers includes the sharing of successful experiences, training, dissemination of research and development results, and financial support from government.

Table 2. Summary of the advantages of the different flooring types

Flooring type	Advantages* For pig welfare	Advantages* Others
Fully slatted	- Good waste drainage => cleanliness of animals and pen - Helps animal thermoregulation during hot weather - Good animal and environmental hygiene => fewer risks of infectious diseases	For farmers: - Moderate input costs (substrates, technical materials) - Low labour costs for cleaning and waste management - Higher animal densities => more cost-effective use of space in the building - Manure/slurry is valorised (spread on fields)
Partly slatted	- Opportunity to divide space into separate activity areas (dunging, resting/sleeping) => helps keep resting/sleeping area clean in cold weather - Fewer foot injuries and less lameness	For farmers: - Moderate input costs (substrates, technical materials) - Low labour costs for cleaning and waste management For the environment and farmers: - Reduced ammonia emissions from the slurry pit reported in some studies (conflicting results) - Less powerful smells than with fully slatted systems
Partly slatted with added straw	- Allows some straw to be provided (preferably chopped): system better for animal welfare => greater expression of exploratory and nest-building behaviours, depending on quantity of straw provided => reduced risk of tail biting, even with small quantities of straw => improved lying comfort => improved thermal comfort in cold weather => improved hygiene of pen and pigs - Fewer foot lesions, less lameness - Less bursitis in sows	For farmers: - Fewer seizures and less downgrading at the abattoir - Less need for veterinary care - Manure/slurry is valorised (spread on fields) For the environment and farmers: - Lower ammonia emissions reported in some studies (conflicting results) - Les powerful smells than with fully slatted systems
Solid, bare	- Improved lying comfort - Fewer negative social interactions - Fewer foot lesions, less lameness	For farmers: - Lower energy costs
Solid, scraped litter	- Opportunity to provide large quantity of litter: system helps animal welfare => greater expression of exploratory and nest-building behaviours, depending on quantity of straw provided => marked reduction in risk of tail biting => improved thermal comfort in cold and hot weather => improved comfort while resting => fewer foot and leg lesions and less lameness => less bursitis in foot and leg joints - Reduced ammonia emissions due to litter's absorption capacity - More space per animal	For farmers: - Fewer seizures and less downgrading at the abattoir - Fewer injuries => less need for veterinary care - Manure/slurry is valorised (spread on fields) - Lower energy costs For the environment and farmers: - Lower ammonia emissions - Less powerful smells than with fully slatted systems
Solid, deep litter system	- Maximum quantity of litter: system helps animal welfare => maximum lying comfort => maximum thermal comfort in cold weather => pen is clean and dry => maximum expression of exploratory behaviour => lowest risk of tail biting => more positive social interactions => improved sow lactation behaviour => improved piglet survival rates => fewer foot and leg injuries and lesions - More space per animal	For farmers: - Few seizures and little downgrading at the abattoir - Little veterinary care - Manure/slurry is valorised (spread on fields) - Lower energy costs For the environment and farmers: - Lower ammonia emissions

* Advantages of alternative flooring systems compared with fully slated flooring

Table 3. Summary of the disadvantages of the different flooring types

Flooring type	Disadvantages*	
	For pig welfare	Others
Fuly slatted	- Little suited to addition of straw or fodder => little opportunity to express exploratory and nest-building behaviours => high risk of tail biting - Risk of injury to fee and legst and lameness, lesions on tails and ears, and bursitis - Risk of temperature stress in cold weather - Higher density => greater risk of agonistic interactions (including tail biting) - Ammonia emissions into the atmosphere => risk of breathing and visual problems => risk factor for tail biting	For the farmer: - Consequences of tail biting: * loss of revenue => downgrading and seizure of carcasses at the abattoir => reduction of gross margin per animal * animal husbandry => more interventions required (treatment of wounded animals, separation of biters and bitten animals and problems when they are returned to the group) => more risks when handling highly stressed animals during serious outbreaks of tail biting For the environment and the farmer: - Ammonia emissions from the slurry pit => pollution of the environment - Unpleasant smells from the slurry pit => pollution of the environment => problems with neighbours
Partly slatted	- Without straw or fodder: => little opportunity to express exploratory and nest-building behaviours => high risk of tail biting - Reduced cleanliness of pen and animals - Increased risk of temperature stress in hot weather => risk of fouling in sleeping area	For the farmer: - Consequences of tail biting: as for fully slatted flooring For the environment and the farmer: - Higher levels of ammonia emissions from the lying area during hot weather in some studies (contradictory results) - Unpleasant smells from the slurry pit: as for fully slatted flooring
Partly slatted with added straw	- Increased risk of temperature stress in hot weather => risk of fouling in sleeping area - If straw is damp, risk of mould developing and producing mycotoxins => risk that animal health will be affected	For the farmer: - More work (scraping the lying area + straw provision and spreading) - Risk that the gaps between the slats will become blocked with unchopped straw - Risk that the evacuation system will become blocked if pipes are too narrow - Cost of straw For the environment and the farmer: as for partly slatted flooring
Solid, bare	- Reduced cleanliness of pen and animals - If bare floor is hard and abrasive: poor lying comfort, risk of injuries and lesions (bursitis, wear on hocks, calluses) - If bare floor is slippery: risk of falls and lameness - If concrete floor is incorrectly cured: increased risk of gastroenteritis	For the farmer: - More work (curing of concrete)
Solid, scraped litter	- If insufficient quantity of straw is provided: => continued risk of tail-biting => continued risk of lameness - If straw is damp: risks of mould developing and producing mycotoxins => risk that animal health will be affected, risk of reduced fertility in sows	For the farmer: - More work: * straw provision and spreading * harder to keep flooring clean, more frequent scraping - Cost of bedding
Solid, deep litter system	- Heat production by litter: => risk of considerable temperature stress in hot weather - Gas emissions from the litter: ammonia, greenhouse gases => risk of breathing and visual problems - Increased risk of suspension of dust particles in the atmosphere => risk of breathing and visual problems - If litter does not break down properly: => risk of contamination from infectious agents	For the farmer: - Capital costs (need for specially designed buildings) - Cost of bedding - Fewer pigs produced - Possible problems with straw supply - More work: * initial installation of bedding * cleaning/disinfecting at the end of the phase For the environment and the farmer: - Gaseous emissions from the bedding: ammonia, greenhouse gases

*Disadvantages of alternative flooring systems compared with fully slatted flooring

Table 4. Summary of recommendations for the improvement of pig welfare

Flooring type	Recommendations for the improvement of pig welfare No alterations to existing building	 Planning of new buildings or renovation of existing buildings
Fully slatted	To enable expression of exploratory behaviours and reduce the risk of tail biting: - Provide litter in small quantities, chopped straw for example - Distribute several types of manipulable objects at once that are regularly replaced and conform to EU Recommendation 2016/336 To improve lying and thermal comfort: - Install rubber mats and clean regularly To improve air quality and reduce risk of breathing and eye problems: - Ensure effective building ventilation - Remove manure/slurry regularly To reduce risk of injury: - Chosse, where possible, slatted flooring: * made of/coated with plastic for piglets * made of non-abrasive materials * with slat and opening sizes in line with Directive 2008/120/EC and suited to the age of the pigs - Check that slats are in good condition	For welfare: avoid fully slatted flooring systems
Partly slatted	To increase lying comfort: - Install rubber mats and clean regularly To limit the risk of tail biting in weaners and fatteners: - Distribute several types of manipulable object at once that are reguarly replaced and conform to EU Recommendation 2016/336 To limit the risk of injury, choose, where possible, slatted flooring - made of/coated with plastic for piglets - made of non-abrasive materials	For welfare: as far as possible, choose partly slatted flooring with straw over slatted flooring without straw. To maximise advantages/minimise disadvantages of partly slatted flooring: - Design housing to take into account (non-exhaustive list): * quality of the materials * position of slatted area and its good ventilation To calculate the optimal proportion of full slatted flooring: - First determine the solid surface area necessary for lying comfort (calculated by the EFSA as 0.77 m^2/pig weighing 110 kg)
Partly slatted with added straw	As for partly slatted flooring without straw, but additionally: To encourage the expression of exploratory and nest-building behaviours without blocking the waste removal system: - Provide straw in the solid-floored area - Consider provision of straw in racks, designed and positioned to suit the physiological development stage of the animals and the size of the stalks - Provide a rubber mat on which to put straw, or under the rack - Provide pregnant sows with nest-building materials (long-stemmed straw, hessian) in a rack in the solid-floored area To avoid the risk of tail biting in weaners and fatteners: - Provide a minimum of 20 g straw/day/animal, and up to 400 g for maximum effect and adjust straw quantity to the amount actually used by the animals - Provide straw to piglets before weaning To facilitate litter spreading and increase lying comfort: - Install rubber mats and clean regularly	As for partly slatted flooring without straw, but additionally: To maximise the advantages/minimise the disadvantages of partly slatted flooring with added straw: - Design housing to take into account: * the need to prevent the displacement of straw from the solid flooring area to the slatted flooring area * the evacuation of waste
Solid, bare	For lying comfort and to reduce limping: - Cover concrete floors with a shock-absorbent or friction-reducing material - Install rubber mats and clean regularly For cleanliness: - Clean the floor regularly	For the cleanliness of the flooring and the animals: - Plan an efficient drainage system - Design a space that encourages the establishment of distinct functional areas To keep injuries and limping to a minimum: - Choose a smooth concrete surface over a rough surface
Solid, raked litter	As for solid floors, but additionally: To maximise exploratory behaviours: - Provide sufficient and appropriate quantities of straw For lying comfort and to reduce limping: - Provide at least 20 g of straw For cleanliness: - Replace soiled litter	As for partially slatted floors without straw.
Solid, deep litter	To keep the litter clean, dry and healthy, and therefore for the comfort of the animals: - Top up straw every 7 to 10 days, prioritising elimination areas To avoid thermal stress: - Provide access to a different flooring type during heat waves To ensure the animals' comfort: - Anticipate the greater height of the litter at the end of the production phase (+ 40 to 50 cm) by raising feeding areas, for example	To facilitate effective working ergonomics and maintenance: - Ensure good design of the building: height of the roof, width of corridors, partitions, feeding areas etc. To allow evaporation of water, restrict gaz emissions and control temperature: - Ensure the building's floor and walls are properly insulated - Design an effective ventilation system

Table 5. Summary of the obstacles and levers associated with the development of alternatives to slatted flooring

<table>
<tr><th rowspan="2">Flooring type</th><th colspan="2">Obstacles and levers for the adoption of alternatives to a fully slatted flooring system*</th></tr>
<tr><th>Obstacles</th><th>Levers</th></tr>
<tr><td>Partly slatted with added straw</td><td>Economic obstacles:
- Costs of infrastructure development (buildings and waste removal system)
- Costs of labour and inputs (substrate)

Technical obstacles:
- Supply of quality bedding
- Workplace ergonomics: time-consuming and demanding work - spreading and scraping of litter
- Lack of knowledge/scepticism among some farmers over the true benefits of manipulable substrates for pig welfare and farm profitability</td><td>Technical levers:
- Little additional work since straw is distributed only in sleeping areas
- Opportunity to combine litter with slatted flooring
- Provision of cut straw avoids obstruction of gaps between slats
- Slurry can be removed without technical changes to buildings by using the floating slurry technique

Societal levers:
- Greater interest in animal welfare
- Societal pressures to change the system</td></tr>
<tr><td>Solid, bare</td><td>Economic obstacles:
- Construction and conversion costs for buildings and labour costs
- Lower stocking density</td><td>Data not available.</td></tr>
<tr><td>Solid, raked litter</td><td rowspan="2">Economic obstacles - main obstacles for farmers:
- Same obstacles as for bare solid floors and cost of inputs (straw)

Technical obstacles:
- Supply of quality bedding in all seasons and years
- Workplace ergonomics: time-consuming and demanding litter replenishment, time-consuming scraping (scraped litter system), monitoring of straw function and condition, disinfection between production phases; working environment (dust)
- Health risk: management of pathogens if litter is poorly managed
- Management complexity: monitoring and management of litter condition, body condition of fattening pigs, temperatures and ventilation
- Lack of knowledge/scepticism among some farmers concerning the true benefits of manipulable substrates for animal welfare and farm profitability for alternative systems

Environmental obstacles:
- Emissions of greenhouse gases and ammonia
- Hard to predict variations in emissions

Societal barriers:
- Resistance to change, pressure from fellow-farmers using fully slatted systems</td><td rowspan="2">Economic levers:
- Adding value to animals: improved valorisation of meat products (quality labels, fewer rejected carcasses at the abattoir with reduced tail biting)
- Fewer veterinary visits
- Valorisation of manure
- Lower energy costs with natural ventilation
- Where needed – financial support in place for change to a litter-based system

Technical levers:
- Workplace ergonomics and comfort:
* mechanisation of tasks
* potential to end tail docking => fewer operations on animals, fewer odours and improved air quality compared with slatted flooring
- Opportunity to convert an existing building: plan operational organisation to reduce working time and effort
- Many ongoing R and D projects on management of litter-based systems: results can be disseminated and communicated
- Success stories can be shared by farmers (farm visits, discussions among fellow farmers)
- Training for agricultural advisors and farmers

Environmental levers:
- Reduction in ammonia emissions can be achieved through proper management of litter
- Manure = quality organic compost
- Reduced water pollution and emissions of noxious odours

Societal levers:
- Improved respect for animal welfare, account taken of consumer expectations
- Improved image of the business of farming
- Greater acceptability of livestock farming
- Satisfaction of farmers at work</td></tr>
<tr><td>Solid, deep litter</td></tr>
</table>

*Due to the lack of data for partly slatted systems without straw, these are not discussed here.

Appendix 1: Background as defined by the commissioning parties in their request for an expert opinion

Tail biting is an expression of impaired welfare in pigs, and its causes are many and variable. Factors explaining the emergence of this behaviour include, in particular, the absence or inadequate provision of enrichment materials in the animal's living environment, excessive stocking densities within pens, too much competition between conspecifics for feed or water, an unsuitable diet (lack of fibre or proteins etc.) and poor air quality, to which can be added genetic predisposition and farming practices, such as re-grouping, that create social tensions within groups of animals (EFSA Panel on AHAW, 2007a; Valros et al, 2016 ; Ramonet and Villain, 2021).

Banned as a routine practice since 1994, tail docking is nevertheless still practiced systematically in France (De Briyne et al., 2018), despite the strengthening of the provisions of Directive 2008/120/EC setting out the measures to be taken to reduce the risks of tail biting. The European Commission's audit of measures in place in France 'to prevent tail biting and avoid routine tail docking of pigs' (2019) revealed that very few concrete measures had been taken to improve compliance with the provisions of this directive.

Of the solutions identified to improve compliance with European regulations, a shift towards the inclusion of solid flooring (both partial and full) in livestock buildings as an alternative to fully slatted floors has been chosen by countries such as Denmark, Sweden and the Netherlands.

Pigs are social animals with very highly developed exploratory needs. Where a pig's environment permits, it will spend the greater part of its activity time foraging, exploring its living environment and searching for food, even when fed *ad libitum* (EFSA Panel on AHAW, 2007a). The main need expressed by active pigs is a rooting-type set of behaviours (i.e. exploring with the snout, chewing and 'digging'). When a pig's behavioural need to investigate is not satisfied, it may express its frustration by redirecting this exploratory behaviour towards conspecifics, increasing the risk of injury and of tail-biting outbreaks (EFSA Panel on AHAW, 2007a). To enable animals to express this exploratory behaviour, it is necessary to provide them with manipulable materials with properties that enable them to root and chew. The use of forage and bedding such as straw is one way of meeting this need. These materials can serve as recreational and/or nutritional substrates, while bedding has the additional advantage of improving the animals' thermal and physical comfort (Day et al., 2002; Valros et al., 2016). However, the addition of manipulable organic materials such as straw appears to be incompatible with 100%-slatted flooring systems (this being the most common flooring type in French livestock farming), as they block the evacuation of slurry in some systems (Anses, 2015) and make it more difficult to spread. To evacuate the manure, it would be necessary to use scrapers (Westin et al., 2013), and this type of set-up is not very common on French farms (Anses, 2015). To overcome this difficulty, some farmers have instead opted for 100% solid floors, either covered with thick bedding (of the deep litter type) or provided with foraging materials, while others have developed what are known as 'mixed' flooring systems, comprising separate solid and slatted areas, that provide pigs with a differentiated, less monotonous environment that better meets their need to organize their living space and, depending on the enrichment provided, to explore this environment.

These flooring types could, depending on their design and/or more or less optimal use, provide animals with sufficient bedding and/or forage to enable them to express their natural behaviours. Various studies have been carried out on the addition of such substrates, either on the floor or in various types of racks, with a particular focus on straw because of its biological suitability for pigs (EFSA Panel on AHAW, 2007a; D'Eath et al, 2014). Some racks would appear more suited to the expression of natural behaviours than others, since ease of access to the straw determines its frequency of use and, therefore, pig activity (Zwicker et al. 2012, Caille et al. 2016). Indeed, the extent of straw-directed behaviours is proportional to the quantity of straw provided – as quantities are increased, animals become less aggressive and are less likely to bite other pigs (Day et al., 2002). To provide pigs with permanent access to clean straw as forage, Pedersen et al (2014) have estimated that a minimum of 400 g of straw per pig per day is required. Even the provision of this minimum amount significantly reduced the incidence of abnormal behaviours in pigs. The authors nevertheless considered that this quantity was not sufficient to fully meet the behavioural needs of pigs. It would be useful to determine the factors that enable optimal use of this flooring type, and to identify the obstacles and levers associated with their introduction. The provision of bedding is regularly cited in the literature as a factor essential to the expression of rooting behaviour in pigs. Further research is needed on the depth of bedding required to enable animals to dig and root.

Last, it would appear important to explore whether these types of flooring should be made available as alternatives to fully slatted flooring at all stages of pig production, including for sows. Indeed, while farming conditions and practices during the post-weaning phase appear to play a decisive role the prevention of the onset of tail biting, it would appear that the maternity phase is also important in this regard (EFSA Panel on AHAW, 2022a). Indeed, access to suitable manipulable materials for piglets from birth appears to have a part to play in the successful rearing of piglets without tail docking. Day et al (2002) have demonstrated that animals who learn to use straw as piglets express significantly less agonistic behaviour later in life. The addition of straw (even in small quantities) at the post-weaning and fattening stages can also help to mitigate the negative effects of changes in housing.

It is also known that the provision of enrichment materials for sows, whether in the gestation phase, immediately before farrowing, or during lactation, contributes to improved welfare and piglet survival. Merlot et al (2017) observed a reduction in stress in pregnant sows housed in a system enriched with straw bedding, along with a reduction in piglet mortality before weaning. For sows at the end of the gestation phase, the presence of a solid floor area in the farrowing pen allows materials to be provided for nest building. This behaviour is essential for sows, who express it even when they are confined and no nesting materials are provided (Pedersen et al., 2013; Yun and Valros, 2015). In these circumstances, sows nest 'in a void', redirecting the oral behaviours specific to the manipulation of materials and nest building towards the bars and equipment in the crate instead (Goumon et al., 2022; Pedersen et al., 2013). During this phase, in which the sow prepares for the arrival of the piglets, numerous hormonal changes influence farrowing and piglet survival in the first few days after birth (Yun and Valros, 2015). Higher oxytocin levels have been observed in free-ranging sows with access to nesting materials. These higher levels accelerate and strengthen uterine contractions while shortening the interval between them, thereby reducing farrowing time and increasing the chances of piglet survival (Choi et al., 2020; Weber et al., 2007). Since slatted flooring in the farrowing pen is not compatible with the provision of rooting materials for sows and piglets, alternative materials are temporarily provided to sows (hessian) and then removed soon after farrowing, but their suitability is open to question. It would be of interest to determine which factors would allow optimal use of solid or partially solid flooring during the maternity and gestation phases, enabling the needs of the sow to be met and the need for piglet tail docking to be eliminated, while identifying the obstacles and levers relating to the implementation of the associated changes.

– ANSES, (2015). Avis de l'ANSES relatif à ' l'enrichissement du milieu d'élevage des porcs par la mise à disposition de matériaux manipulables', suite à la saisine N°203-SA-0180.
– Caille ME., Loussouarn A., (2016). Inputs of straw and other handling materials in a room equipped with V-scrapers. Study report. Chambres d'agriculture de Bretagne, 8 pages.
– Choi, Y., Min, Y., Kim, Y., Jeong, Y., Kim, D., Kim, J., & Jung, H. (2020). Effects of loose farrowing facilities on reproductive performance in primiparous sows. Journal of Animal Science and Technology, 62(2), 218-226.
– Day J.E.L., Burfoot A., Docking C.M., Whittaker X., Spoolder H.A.M., Edwards S.A., (2002). The effect of prior experience of straw and the level of straw provision on the behaviour of growing pigs. Applied Animal Behaviour Science, 76: 189-2002.

– De Briyne, N., Berg, C., Blaha, T., Palzer, A., Temple, D. (2018). Phasing out pig tail docking in the EU - present state, challenges and possibilities. Porcine Health Management, 4, 27.
– D'Eath RB., Arnott G., Turner SP., Jensen T., Lahrmann HP., Busch ME., Niemi JK., Lawrence AB., Sandøe P. (2014). Injurious tail biting in pigs: how can it be controlled in existing systems without tail docking? Animal. Sep;8(9):1479-97. doi: 10.1017/S1751731114001359. PMID: 25130712.
– EFSA, (2007). The risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. The EFSA Journal, 611, 1-13.
– EFSA Panel on Animal Health and Welfare (AHAW). (2022). Welfare of pigs on farm. EFSA Journal 2022;20(8):7421
– Goumon, S., Illmann, G., Moustsen, V. A., Baxter, E. M., & Edwards, S. A. (2022). Review of Temporary Crating of Farrowing and Lactating Sows. Frontiers in Veterinary Science, 9. https://www.frontiersin.org/article/10.3389/fvets.2022.811810
– Merlot, E., Calvar, C. and Prunier, A. (2017). Influence of the housing environment during sow gestation on maternal health, and offspring immunity and survival. Animal Production Science 57, 1751-1758.
– Pedersen, L.J., Malmkvist, J., & Andersen, H. M. L. (2013). Housing of sows during farrowing: A review on pen design, welfare and productivity. In A. Aland & T. Banhazi (Eds.), Livestock housing (pp. 93-112). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-771-4_0
– Pedersen, L.J., Mette S. Herskin, Björn Forkman, Ulrich Halekoh, Kristian M. Kristensen, Margit B. Jensen, (2014). How much is enough? The amount of straw necessary to satisfy pigs' need to perform exploratory behaviour, Applied Animal Behaviour Science, Volume 160, 46-55.
– Ramonet, Y., Villain, N., (2021). Raising whole-tail pigs on litter. Effect of Duroc and Piétrain male genetics on performance and tail condition. Chambre d'agriculture de Bretagne. 9 pages.
– Valros, A., Munsterhjelm, C., Hänninen, L., Kauppinen, T., Heinonen, M., (2016). Managing undocked pigs: on-farm prevention of tail biting and attitudes towards tail biting and docking. Porcine Health Management, 2, 2.
– Weber, R., Keil, N. M., Fehr, M., & Horat, R. (2007). Piglet mortality on farms using farrowing systems with or without crates. Animal Welfare-Potters Bar Then Wheathampstead-, 16(2), 277.
– Westin, R., Holmgren, N., Mattsson, B., Algers, B. (2013) Throughput capacity of large quantities of chopped straw in partly slatted farrowing pens for loose housed sows. Acta Agriculturae Scandinavica, Section A - Animal Science, 63(1) 18-27.
– Zwicker, B., Gygax, L., Wechsler, B., Weber, R., (2012). Influence of accessibility of straw in racks on exploratory behaviour in finishing pigs. Livestock Science, vol 148, p67-73

Appendix 2: Compiling the bibliographical corpus

Systematic search

A Web of Science (https://www.webofscience.com/) search request was made as follows: ''pig and floor* and slat* and behavio*'; 'pig and floor* and (bedding or litter or enrichment material) and behavio*', 'Pig and floor* and 'nest-building' and behavio*', 'Pig and floor* and behavio* and 'enrichment material''. Duplicates were deleted. Selection of relevant articles was based on abstracts.
Thus constituted, the bibliographic corpus contained 82 references.

A reading template was established with the following headings: Article reference; Soil type; Soil details; Litter present; Litter details; Forage present; Forage details; Animal category; Effect on manipulative behaviours; Effect on exploratory behaviours; Effect on posture/rest/movement; Effect on agonistic interactions; Effect on positive social interactions; Effect on maternal behaviours; Effect on elimination behaviours; Other effects.

The template was used in reading the 82 articles and extracting the relevant information.

Targeted search

This search was based on the reading of the following scientific syntheses:
- Avis du CNR BEA sur les implications de l'avis EFSA au sujet du bien-être des porcs pour les élevages en France (CNR BEA, 2024)
- Physiological and behavioural characteristics and requirements of pigs (CNR BEA, 2023)
- Welfare of pigs on farm (EFSA Panel on AHAW, 2022a)
- Avis de l'Anses relatif à 'l'enrichissement du milieu d'élevage des porcs par la mise à disposition de matériaux manipulables' (Anses, 2015)
- Scientific opinion concerning a multifactorial approach on the use of animal and non-animal-based measures to assess the welfare of pigs (EFSA Panel on AHAW, 2014)
- The risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems (EFSA Panel on AHAW, 2007a)
- Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to animal health and welfare in fattening pigs in relation to housing and husbandry (EFSA Panel on AHAW, 2007b)
- Scientific report 'The welfare of weaners and rearing pigs: effects of different space allowances and floor types' (EFSA Panel on AHAW, 2005)

It was supplemented by references cited by the requesting body in the referral document, by references recommended by the experts consulted, references identified during the reading phase, and a targeted search of the IFIP documentary database (https://ifip.asso.fr/documentations/).

Creation of the finalised bibliographical corpus

Documents from both searches were compared and duplicates removed. The finalised corpus contained 252 documents.
This corpus was used to search for additional information not identified in the systematic analysis carried out on the initial corpus of 82 articles, and to obtain clarifications on information provided by scientific syntheses.

Figure 10 provides a summary of the above methodology.

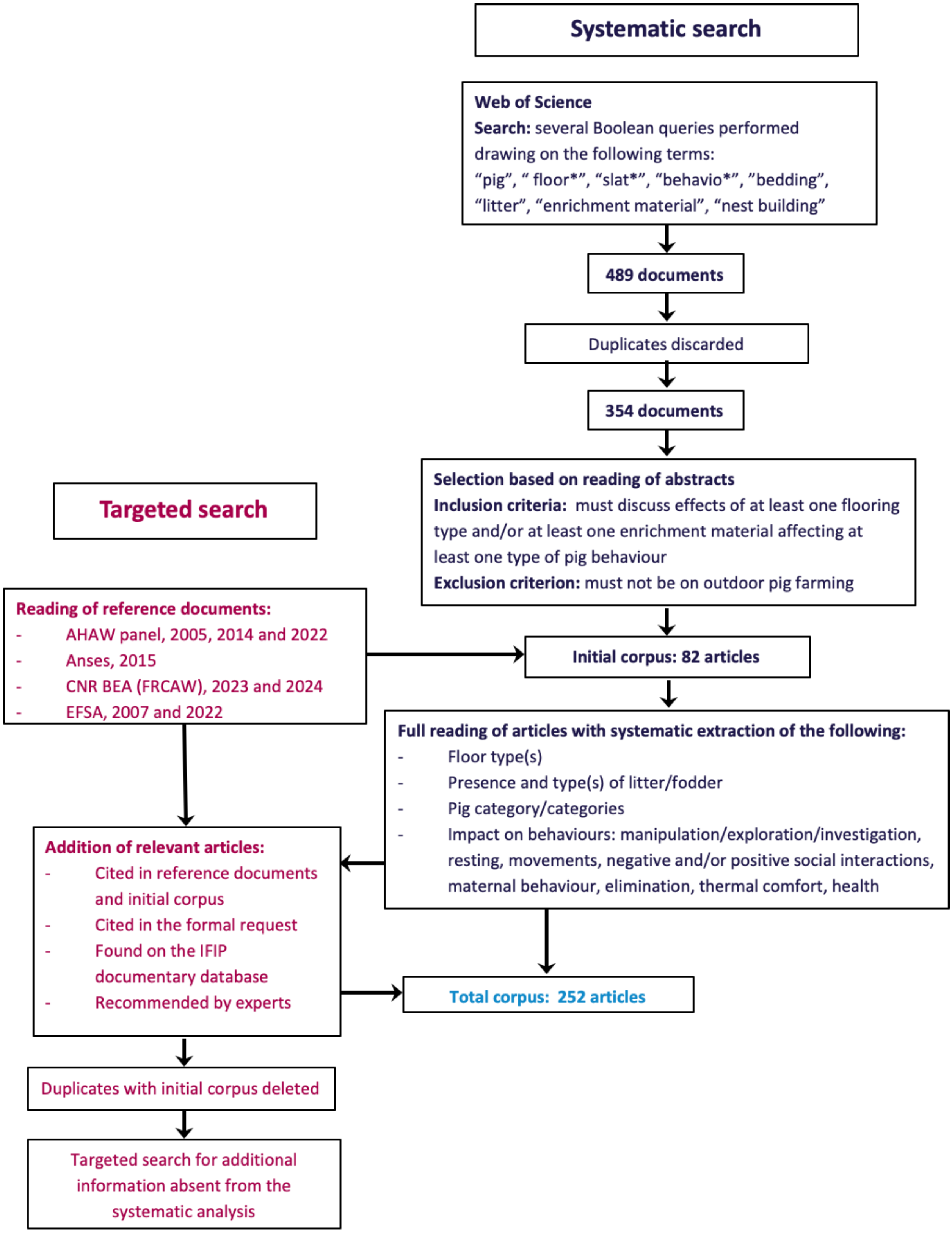

Figure 10. Creation of the bibliographical corpus

Appendix 3: Extracts from the European regulatory framework on floor types and the use of manipulable materials on pig farms

European legislation

Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (European Commission, 2008)

Article 3. 1. Member States shall ensure that all holdings comply with the following requirements:
(a) the unobstructed floor area available to each weaner or rearing pig kept in a group, excluding gilts after service and sows, must be at least:

Live weight (kg)	m^2
Not more than 10	0.15
More than 10 but not more than 20	0.20
More than 20 but not more than 30	0.30
More than 30 but not more than 50	0.40
More than 50 but not more than 85	0.55
More than 85 but not more than 110	0.65
More than 110	1.00

2. Member States shall ensure that flooring surfaces comply with the following requirements:

(a) for gilts after service and pregnant sows: a part of the area required in paragraph 1(b), equal to at least 0,95 m^2 per gilt and at least 1,3 m^2 per sow, must be of continuous solid floor of which a maximum of 15 % is reserved for drainage openings;

(b) when concrete slatted floors are used for pigs kept in groups:

(i) the maximum width of the openings must be:

— 11 mm for piglets,

— 14 mm for weaners,

— 18 mm for rearing pigs,

— 20 mm for gilts after service and sows;

(ii) the minimum slat width must be:

— 50 mm for piglets and weaners, and

— 80 mm for rearing pigs, gilts after service and sows.

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 1, Chapter I:
3. The accommodation for pigs be constructed in such a way as to allow the animals to:
- 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. […]
4. […] 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.
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.
8. […] Tail docking must [not] be carried out routinely, but only where there is evidence that injuries to […] other pigs' […] tails. Before carrying out these procedures, other measures shall be taken to prevent tail-biting and other vices, taking into account environment and stocking densities. For this reason, inadequate environmental conditions or management systems must be changed.

Annex 1, Chapter II:
Sows and gilts: In the week preceding the expected farrowing time, sows and gilts must be given suitable nesting material in sufficient quantity unless it is not technically feasible for the slurry system used in the establishment.
Piglets: A part of the total floor, sufficient to allow the animals to rest together at the same time, must be solid or covered with a mat, or be littered with straw or any other suitable material.
Weaners and rearing pigs: When signs of severe fighting appear the causes shall be immediately investigated and appropriate measures taken, such as providing plentiful straw to the animals, if possible, or other materials for investigation.

Commission Recommendation EU 2016/336 of March 8, 2016 on the application of Council Directive 2008/120/EC (European Commission, 2016)

Summary by the FRCAW. In order to prevent tail biting, this recommendation calls for certain improvements in farming practices, including the use of enrichment materials. It recommends that enrichment materials should be safe and have the following characteristics: edible, chewable, investigable, manipulable, accessible for oral manipulation, of sustainable interest (that is to say they should encourage the exploratory behaviour of pigs and be regularly replaced and replenished), given in sufficient quantity, and clean and hygienic.
The recommendation establishes three categories of enrichment materials: optimal materials - possessing all the above characteristics and therefore can be used alone: sub-optimal materials - possessing most of the above characteristics and therefore should be used in combination with other materials - and materials of marginal interest – providing distraction to pigs but should not be considered as fulfilling their essential needs, and therefore should be used in conjunction with optimal or sub-optimal materials.

French legislation

Arrêté du 17 novembre 2021 modifiant l'Arrêté du 16 janvier 2003 établissant les normes minimales relatives à la protection des porcs. [Decree of 17 November 2021 altering the Decree of 16 January 2003 establishing the minimum standards relating to pig welfare] (French Ministry of Agriculture and Food, 2021)

This decree on the minimum acceptable standards for pig welfare takes French mandatory requirements beyond the European regulations on the following points [translated from the French]:

Appendix, Chapter I: The type and quantity of manipulable materials required are as follows (based on the definitions found in Commission Recommendation (EU) 2016/336 of March 8, 2016):
- for pens containing up to 25 pigs: at least one optimal material or one suboptimal material and one material of marginal interest;

- for pens containing 26 to 40 pigs: at least one optimal material, or two sub-optimal materials (or one if more than two pigs can access it simultaneously), and one of marginal interest;
- for pens containing more than 40 pigs: at least one optimal material or two sub-optimal materials and two materials of marginal interest (or one if more than two pigs can access it simultaneously);
- in the specific case of pens containing up to 10 breeding sows, boars in individual pens, and gilts and breeding sows in individual stalls: at least one optimal or sub-optimal material.

Bibliography

Aarnink, A.J.A., Hoeksma, P., Ouwerkerk, E.N.J., 1993. Factors affecting ammonium concentration in slurry from fattening pigs, in: Nitrogen Flow in Pig Production and Environmental Consequences: Proceedings of the First International Symposium on Nitrogen Flow in Pig Production and Environmental Consequences. Wageningen, pp. 413–420. https://edepot.wur.nl/317111

Aarnink, A.J.A., Schrama, J.W., Heetkamp, M.J.W., Stefanowska, J., Huynh, T.T.T., 2006. Temperature and body weight affect fouling of pig pens. J. Anim. Sci. 84, 2224–2231. https://doi.org/10.2527/jas.2005-521

Aarnink, A.J.A., Schrama, J.W., Verheijen, R.J.E., Stefanowska, J., 2001. Pen Fouling in Pig Houses Affected by Temperature, in: Livestock Environment VI: Proceedings of the 6th International Symposium. ED. Richard R. Stowell, Ray Bucklin, and Robert W. Bottcher, Louisville, Kentucky, USA, pp. 180–186. https://doi.org/10.13031/2013.7071

Aarnink, A.J.A., Swierstra, D., van den Berg, A.J., Speelman, L., 1997. Effect of Type of Slatted Floor and Degree of Fouling of Solid Floor on Ammonia Emission Rates from Fattening Piggeries. J. Agric. Eng. Res. 66, 93–102. https://doi.org/10.1006/jaer.1996.0121

Aarnink, A.J.A., Van Den Berg, A.J., Keen, A., Hoeksma, P., Verstegen, M.W.A., 1996. Effect of Slatted Floor Area on Ammonia Emission and on the Excretory and Lying Behaviour of Growing Pigs. J. Agric. Eng. Res. 64, 299–310. https://doi.org/10.1006/jaer.1996.0071

Aarnink, A. J. A., van den Berg, A.J., Keen, A., Hoeksma, P., Verstegen, M.W.A., 1996. Effect of Slatted Floor Area on Ammonia Emission and on the Excretory and Lying Behaviour of Growing Pigs. J. Agric. Eng. Res. 64, 299–310. https://doi.org/10.1006/jaer.1996.0071

Andersen, H.M.-L., Dybkjær, L., Herskin, M.S., 2014. Growing pigs' drinking behaviour: number of visits, duration, water intake and diurnal variation. Animal 8, 1881–1888. https://doi.org/10.1017/S175173111400192X

Andersen, H.M.-L., Kongsted, A.G., Jakobsen, M., 2020. Pig elimination behavior—A review. Appl. Anim. Behav. Sci. 222, 104888. https://doi.org/10.1016/j.applanim.2019.104888

Andersen, I.L., Bøe, K.E., Kristiansen, A.L., 1999. The influence of different feeding arrangements and food type on competition at feeding in pregnant sows. Appl. Anim. Behav. Sci. 65, 91–104. https://doi.org/10.1016/S0168-1591(99)00058-1

Anses, 2018. Avis de l'Anses relatif au « Bien-être animal : contexte, définition et évaluation ». https://www.anses.fr/fr/system/files/SABA2016SA0288.pdf

Anses, 2015. Avis de l'Anses relatif à « l'enrichissement du milieu d'élevage des porcs par la mise à disposition de matériaux manipulables ». https://www.anses.fr/fr/system/files/SANT2013sa0180.pdf

Appleby, M.C., Wood-Gush, D.G.M., 1988. Effect of earth as an additional stimulus on the behaviour of confined piglets. Behav. Processes 17, 83–91. https://doi.org/10.1016/0376-6357(88)90027-7

Arey, D.S., 1992. Straw and food as reinforcers for prepartal sows. Appl. Anim. Behav. Sci. 33, 217–226. https://doi.org/10.1016/S0168-1591(05)80009-7

Arey, D.S., Petchey, A.M., Fowler, V.R., 1991. The preparturient behaviour of sows in enriched pens and the effect of pre-formed nests. Appl. Anim. Behav. Sci. 31, 61–68. https://doi.org/10.1016/0168-1591(91)90153-O

Averos, X., Brossard, L., Dourmad, J.-Y., de Greef, K.H., Edge, H.L., Edwards, S.A., Meunier-Salaun, M.-C., 2010. A meta-analysis of the combined effect of housing and environmental enrichment characteristics on the behaviour and performance of pigs. Appl. Anim. Behav. Sci. 127, 73–85. https://doi.org/10.1016/j.applanim.2010.09.010

Barnett, J.L., Hemsworth, P.H., Cronin, G.M., Jongman, E.C., Hutson, G.D., 2001. A review of the welfare issues for sows and piglets in relation to housing. Aust. J. Agric. Res. 52, 1-28. https://doi.org/10.1071/AR00057

Baxter, E.M., Lawrence, A.B., Edwards, S.A., 2011. Alternative farrowing systems: design criteria for farrowing systems based on the biological needs of sows and piglets. Animal 5, 580–600. https://doi.org/10.1017/S1751731110002272

Beattie, V.E., O'Connell, N.E., 2002. Relationship Between Rooting Behaviour and Foraging in Growing Pigs. Anim. Welf. 11, 295–303. https://doi.org/10.1017/S0962728600024878
Beattie, V.E., O'Connell, N.E., Moss, B.W., 2000. Influence of environmental enrichment on the behaviour, performance and meat quality of domestic pigs. Livest. Prod. Sci. 65, 71–79. https://doi.org/10.1016/S0301-6226(99)00179-7
Beattie, V.E., Sneddon, I.A., Walker, N., Weatherup, R.N., 2001. Environmental enrichment of intensive pig housing using spent mushroom compost. Anim. Sci. 72, 35–42. https://doi.org/10.1017/S1357729800055533
Beattie, V.E., Walker, N., Sneddon, I.A., 1998. Preference Testing of Substrates by Growing Pigs. Anim. Welf. 7, 27–34. https://doi.org/10.1017/S0962728600020236
Beattie, V.E., Walker, N., Sneddon, I.A., 1996. An investigation of the effect of environmental enrichment and space allowance on the behaviour and production of growing pigs. Appl. Anim. Behav. Sci. 48, 151–158. https://doi.org/10.1016/0168-1591(96)01031-3
Beattie, V.E., Walker, N., Sneddon, I.A., 1995. Effects of Environmental Enrichment on Behaviour and Productivity of Growing Pigs. Anim. Welf. 4, 207–220. https://doi.org/10.1017/S0962728600017802
Bench, C.J., Gonyou, H.W., 2006. Effect of environmental enrichment at two stages of development on belly nosing in piglets weaned at fourteen days1. J. Anim. Sci. 84, 3397–3403. https://doi.org/10.2527/jas.2006-050
Blackshaw, J.K., Thomas, F.J., Lee, J.-A., 1997. The effect of a fixed or free toy on the growth rate and aggressive behaviour of weaned pigs and the influence of hierarchy on initial investigation of the toys. Appl. Anim. Behav. Sci. 53, 203–212. https://doi.org/10.1016/S0168-1591(96)01087-8
Bodin, L., Algers, B., Andersson, M., Olsson, AC., Botermans, J., 2015. The Amount of Straw for Growing-Finishing Pigs Considering the Reduction of Time Spent in Manipulative Behavior. SOJ Vet. Sci. 1, 1–6. https://doi.org/10.15226/2381-2907/1/1/00105
Boissy, A., Manteuffel, G., Jensen, M.B., Moe, R.O., Spruijt, B., Keeling, L.J., Winckler, C., Forkman, B., Dimitrov, I., Langbein, J., Bakken, M., Veissier, I., Aubert, A., 2007. Assessment of positive emotions in animals to improve their welfare. Physiol. Behav. 92, 375–397. https://doi.org/10.1016/j.physbeh.2007.02.003
Bolhuis, J.E., Raats-van den Boogaard, A.M.E., Hoofs, A.I.J., Soede, N.M., 2018. Effects of loose housing and the provision of alternative nesting material on peri-partum sow behaviour and piglet survival. Appl. Anim. Behav. Sci. 202, 28–33. https://doi.org/10.1016/j.applanim.2018.01.004
Boon, C.R., Wray, C., 1989. Building design in relation to the control of diseases of intensively housed livestock. J. Agric. Eng. Res. 43, 149–161. https://doi.org/10.1016/S0021-8634(89)80014-9
Bornett, H.L.I., Guy, J.H., Cain, P.J., 2003. Impact of Animal Welfare on Costs and Viability of Pig Production in the UK. J. Agric. Environ. Ethics 16, 163–186. https://doi.org/10.1023/A:1022994131594
Boyle, L.A., Regan, D., Leonard, F.C., Lynch, P.B., Brophy, P., 2000. The Effect of Mats on the Welfare of Sows and Piglets in the Farrowing House. Anim. Welf. 9, 39–48. https://doi.org/10.1017/S0962728600022235
Bracke, M.B.M., Zonderland, J.J., Lenskens, P., Schouten, W.G.P., Vermeer, H., Spoolder, H.A.M., Hendriks, H.J.M., Hopster, H., 2006. Formalised review of environmental enrichment for pigs in relation to political decision making. Appl. Anim. Behav. Sci. 98, 165–182. https://doi.org/10.1016/j.applanim.2005.08.021
Brennan, J.J., Aherne, F.X., 1987. Effect of floor type on the severity of foot lesions and osteochondrosis in swine. Can. J. Anim. Sci. 67, 517–523. https://doi.org/10.4141/cjas87-050
Burri, M., Wechsler, B., Gygax, L., Weber, R., 2009. Influence of straw length, sow behaviour and room temperature on the incidence of dangerous situations for piglets in a loose farrowing system. Appl. Anim. Behav. Sci. 117, 181–189. https://doi.org/10.1016/j.applanim.2008.12.005
Caille, M.-E., Loussouarn, A., 2016. Apport de paille et autres matériaux de manipulation pour des porcs charcutiers logés dans une salle équipée de racleurs en V. Chambre d'agriculture de Bretagne. https://opera-connaissances.chambres-agriculture.fr/doc_num.php?explnum_id=171300
Caldara, F.R., Garcia, R.G., de Lima Almeida Paz, I.C., Naeaes, I. de A., Silva dos Santos, R. de K., Foppa, L., 2014. Assessing the most suitable floor system for growing-finishing piggery under

tropical conditions using the analytic hierarchy process. Ital. J. Anim. Sci. 13. https://doi.org/10.4081/ijas.2014.2830
Camerlink, I., 2014. Sociable swine: indirect genetic effects on growth rate and their effect on behaviour and production of pigs in different environments. http://library.wur.nl/WebQuery/wda/2060806
Candotti, P., Rota Nodari, S., Archetti, I., De Angelis, E., Caldara, G., Borghetti, P., 2004. Influence of floor type on the incidence and severity of leg weakness syndrome and of articular osteochondrosis in Italian heavy pig. In: Proceedings of the International Society for Animal Hygiene. https://www.isah-soc.org/userfiles/downloads/symposiums/2004/Candotti.pdf
Centre National de Ressources Textuelles et Lexicales, n.d. Fourrage : définition [WWW Document]. URL https://www.cnrtl.fr/definition/fourrage (consulté le 17/07/24).
Centre National de Ressources Textuelles et Lexicales. Litière : définition [WWW Document]. URL https://www.cnrtl.fr/definition/academie8/liti%C3%A8re//0 (consulté le 17/07/24).
Chambre d'agriculture de Bretagne, 2024. Une liberté de mouvement pour les truies à tous les stades [WWW Document]. URL https://bretagne.chambres-agriculture.fr/mes-productions/elevage/porcs/bien-etre-animal/liberte-de-mouvement-pour-les-truies/ (consulté le 16/06/2024).
Chambre d'agriculture de Bretagne, Chambre d'agriculture des pays de la Loire, IFIP, INRA, 2012. Elever des porcs sur litière - Comprendre les fonctionnements, améliorer les résultats. https://bretagne.chambres-agriculture.fr/fileadmin/user_upload/National/FAL_commun/publications/Bretagne/PDF/Elevage/Porcs/Elever_des_porcs_sur_litiere.pdf
Chambres d'agriculture de France, IFIP, FNP, COOP de France, INAPORC, AVPO, SNGTV, 2019. Fiche technique matériaux manipulables. https://www.leporc.com/assets/fiche_matmanipulablesporc-1681742044.pdf
Clouard, C., Resmond, R., Prunier, A., Tallet, C., Merlot, E., 2022. Exploration of early social behaviors and social styles in relation to individual characteristics in suckling piglets. Sci. Rep. 12, 2318. https://doi.org/10.1038/s41598-022-06354-w
CNR BEA, 2024. Avis du CNR BEA sur les implications de l'avis EFSA au sujet du bien-être des porcs pour les élevages en France. https://www.cnr-bea.fr/en/expertise-travaux/analyse-francaise-de-lavis-efsa-sur-les-porcs/
CNR BEA, 2023. Physiological and behavioural characteristics and needs of pigs Sus scrofa domesticus, https://www.cnr-bea.fr/en/expertise-travaux/caracteristiques-et-besoins-physiologiques-et-comportementaux-du-porc/
Colina, J.J., Lewis, A.J., Mille, P.S., 2000. A review of the ammonia issue and pork production. Neb. Swine Rep. 24–25. https://digitalcommons.unl.edu/coopext_swine/108
Commission européenne, 2017. Conclusions sur les MTD pour les « élevages intensifs de volailles ou de porcs ». https://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=CELEX:32017D0302&from=HR
Courboulay, V., 2019. Paille ou objets à manipuler : quelle attractivité pour le porc en croissance logé sur caillebotis ? [WWW Document]. IFIP. URL https://ifip.asso.fr/actualites/paille-ou-objets-a-manipuler-que-choisir-pour-le-porc-sur-caillebotis/ (consulté le 16/02/2024).
Courboulay, V., 2006. Intérêts comparés d'un objet fixé au sol ou d'un apport de paille comme matériaux d'enrichissement du milieu de vie pour le porc à l'engrais. Journ. Rech. Porc. 38, 421–426. https://www.journees-recherche-porcine.com/texte/2006/06BienEtre/be03.pdf
Courboulay, V., Bregeon, A., Massabie, P., Meunier-Salaün, M.-C., 2003. Incidence du type de sol (caillebotis partiel/caillebotis intégral) et de la taille de la case sur le bien-être des porcs charcutiers. Journ. Rech. Porc. 35, 163-170. https://www.journees-recherche-porcine.com/texte/2003/03txtBienetre/b0303.pdf
https://www.journees-recherche-porcine.com/texte/2003/03txtBienetre/b0303.pdf
Courboulay, V., Delarue, E., Eugène, A., 2008. Évaluation du bien-être des porcs : comparaison d'élevages sur litière ou sur caillebotis. Journ. Rech. Porc. 40, 243–250. https://docs.ifip.asso.fr/pro/ils/DigitalCollection/DigitalCollectionAttachmentDownloadHandler.ashx?parentDocumentId=7795&documentId=14231

Courboulay, V., Drouet, A., 2018. Evaluation de la prévalence de caudophagie par la notation des carcasses en abattoir. Journ. Rech. Porc. 50, 333–334. https://www.journees-recherche-porcine.com/texte/2018/bienetre/b13.pdf
Courboulay, V., Eugène, A., Delarue, E., 2009. Welfare assessment in 82 pig farms: effect of animal age and floor type on behaviour and injuries in fattening pigs. Anim. Welf. 18, 515–521. https://doi.org/10.1017/S0962728600000932
Dalal, D.S. Bursite - Troubles musculosquelettiques et du tissu conjonctif [WWW Document]. Édition Prof. Man. MSD. URL https://www.msdmanuals.com/fr/professional/troubles-musculosquelettiques-et-du-tissu-conjonctif/affections-des-bourses-articulaires,-des-muscles-et-des-tendons/bursite (consulté le 17/07/24).
Damm, B.I., Heiskanen, T., Pedersen, L.J., Jørgensen, E., Forkman, B., 2010. Sow preferences for farrowing under a cover with and without access to straw. Appl. Anim. Behav. Sci. 126, 97–104. https://doi.org/10.1016/j.applanim.2010.06.009
Damm, B.I., Lisborg, L., Vestergaard, K.S., Vanicek, J., 2003. Nest-building, behavioural disturbances and heart rate in farrowing sows kept in crates and Schmid pens. Livest. Prod. Sci. 80, 175–187. https://doi.org/10.1016/S0301-6226(02)00186-0
Damm, B.I., Pedersen, L.J., Heiskanen, T., Nielsen, N.P., 2005. Long-stemmed straw as an additional nesting material in modified Schmid pens in a commercial breeding unit: effects on sow behaviour, and on piglet mortality and growth. Appl. Anim. Behav. Sci. 92, 45–60. https://doi.org/10.1016/j.applanim.2004.10.013
Damm, B.I., Vestergaard, K.S., Schrøder-Petersen, D.L., Ladewig, J., 2000. The effects of branches on prepartum nest building in gilts with access to straw. Appl. Anim. Behav. Sci. 69, 113–124. https://doi.org/10.1016/S0168-1591(00)00122-2
Dantzer, R., 1986. Symposium on “Indices to Measure Animal Well-Being”: Behavioral, Physiological and Functional Aspects of Stereotyped Behavior: A Review and a Re-Interpretation. J. Anim. Sci. 62, 1776–1786. https://doi.org/10.2527/jas1986.6261776x
Davies, P.R., Morrow, W.E.M., Jones, F.T., Deen, J., Fedorka-Cray, P.J., Harris, I.T., 1997. Prevalence of salmonella in finishing swine raised in different production systems in North Carolina, USA, in: Epidemiol. Infect. pp. 237–244. https://doi.org/10.1017/S095026889700784X
Day, J.E.L., Burfoot, A., Docking, C.M., Whittaker, X., Spoolder, H.A.M., Edwards, S.A., 2002. The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 76, 189–202. https://doi.org/10.1016/S0168-1591(02)00017-5
Day, J.E.L., Van de Weerd, H.A., Edwards, S.A., 2008. The effect of varying lengths of straw bedding on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 109, 249–260. https://doi.org/10.1016/j.applanim.2007.02.006
De Briyne, N., Berg, C., Blaha, T., Palzer, A., Temple, D., 2018. ‘Phasing out pig tail docking in the EU - present state, challenges and possibilities.’ Porc. Health Manag. 4, 27. https://doi.org/10.1186/s40813-018-0103-8
De Jonge, F.H., Tilly, S.-L., Baars, A.M., Spruijt, B.M., 2008. On the rewarding nature of appetitive feeding behaviour in pigs (Sus scrofa): Do domesticated pigs contrafreeload? Appl. Anim. Behav. Sci. 114, 359–372. https://doi.org/10.1016/j.applanim.2008.03.006
D’Eath, R.B., Arnott, G., Turner, S.P., Jensen, T., Lahrmann, H.P., Busch, M.E., Niemi, J.K., Lawrence, A.B., Sandøe, P., 2014. Injurious tail biting in pigs: how can it be controlled in existing systems without tail docking? Animal 8, 1479–1497. https://doi.org/10.1017/S1751731114001359
Díaz, J.A.C., Fahey, A.G., KilBride, A.L., Green, L.E., Boyle, L.A., 2013. Longitudinal study of the effect of rubber slat mats on locomotory ability, body, limb and claw lesions, and dirtiness of group housed sows1. J. Anim. Sci. 91, 3940–3954. https://doi.org/10.2527/jas.2012-5913
Ducreux, E., Aloui, B., Robin, P., Dourmad, J.-Y., Courboulay, V., Meunier-Salaün, M.-C., 2002. Les porcs affichent leurs préférences vis-à-vis du type de sol en fonction de la température ambiante. Journ. Rech. Porc. 34, 211–216. https://www.journees-recherche-porcine.com/texte/2002/02txtBienetre/BE0202.pdf
Durrell, J., Sneddon, I.A., Beattie, V.E., 1997. Effects of Enrichment and Floor Type on Behaviour of Cubicle Loose-Housed Dry Sows. Anim. Welf. 6, 297–308. https://doi.org/10.1017/S0962728600020017

Dybkjær, L., 1992. The identification of behavioural indicators of ‘stress’ in early weaned piglets. Appl. Anim. Behav. Sci. 35, 135–147. https://doi.org/10.1016/0168-1591(92)90004-U

Edwards, S.A., Lightfoot, A.L., 1986. The effect of floor type in farrowing pens on pig injury. II. Leg and teat damage of sows. Br. Vet. J. 142, 441–445. https://doi.org/10.1016/0007-1935(86)90045-X

EFSA Panel on AHAW, 2022a. Welfare of pigs on farm. EFSA J. 20, e07421. https://doi.org/10.2903/j.efsa.2022.7421

EFSA Panel on AHAW, 2022b. Methodological guidance for the development of animal welfare mandates in the context of the Farm to Fork Strategy. EFSA J. 20. https://doi.org/10.2903/j.efsa.2022.7403

EFSA Panel on AHAW, 2014. Scientific Opinion concerning a Multifactorial approach on the use of animal and non-animal-based measures to assess the welfare of pigs. EFSA J. 12, 3702. https://doi.org/10.2903/j.efsa.2014.3702

EFSA Panel on AHAW, 2007a. The risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems - Scientific Opinion of the Panel on Animal Health and Welfare. EFSA J. 611, 1-13. https://doi.org/10.2903/j.efsa.2007.611

EFSA Panel on AHAW, 2007b. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to animal health and welfare in fattening pigs in relation to housing and husbandry. EFSA J. 5, 564. https://doi.org/10.2903/j.efsa.2007.564

EFSA Panel on AHAW, 2005. Scientific report “The welfare of weaners and rearing pigs: effects of different space allowances and floor types”: EFSA-Q-2004-077. EFSA J. 268, 1-19. https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2005.268

Ekkel, E.D., Spoolder, H.A.M., Hulsegge, I., Hopster, H., 2003. Lying characteristics as determinants for space requirements in pigs. Appl. Anim. Behav. Sci. 80, 19–30. https://doi.org/10.1016/S0168-1591(02)00154-5

Eläinten Hyvinvointikeskus, 2023. Animal Welfare in Finland. https://www.elaintieto.fi/wp-content/uploads/2024/04/Animal-Welfare-in-Finland-III.pdf

Elmore, M.R.P., Garner, J.P., Johnson, A.K., Kirkden, R.D., Richert, B.T., Pajor, E.A., 2011. Getting around social status: Motivation and enrichment use of dominant and subordinate sows in a group setting. Appl. Anim. Behav. Sci. 133, 154–163. https://doi.org/10.1016/j.applanim.2011.05.017

Enting, J., Vermeij, I., Bosma, A.J.J., van Buiten, A., 2006. Level playing field in de varkenshouderij : implementatie, interpretatie en controle op naleving ven EU-richtlijnen voor de varkenshouderij, Animal Sciences Group Wageningen UR. https://edepot.wur.nl/33726

Espagnol, S., Guingand, N., Genermont, S., Hassouna, M., 2015. Efficacité sur les émissions gazeuses d’itinéraires techniques en élevage porcin intégrant des bonnes pratiques environnementales. Journ. Rech. Porc. 171–176. https://www.journees-recherche-porcine.com/texte/2015/enviro/04E.pdf

EU Platform on Animal Welfare, 2023. Minutes of the 10th meeting of the sub-group on the welfare of pigs (No. 10th). https://food.ec.europa.eu/document/download/bb51e535-8ca0-4d63-826a-33007db621ac_en?filename=aw_platform_20230508_sub-pigs_min.pdf

EURCAW-Ruminants & Equines, 2023. Enrichissement de l’environnement pour les bovins. https://www.eurcaw-ruminants-equines.eu/wp-content/uploads/2022/10/TFS-Ruminants-Equines-2023-05-FR-Enrichment-for-cattle.pdf

European Commission, 2017. Commission Implementing Decision (EU) 2017/302 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU, for the intensive rearing of poultry or pigs. https://eur-lex.europa.eu/eli/dec_impl/2017/302/oj/eng

European Commission, 2016. Commission Recommendation (EU) 2016/336 of 8 March 2016 on the application of Council Directive 2008/120/EC laying down minimum standards for the protection of pigs as regards measures to reduce the need for tail-docking. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A32016H0336

European Commission, 2008. Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0120

European Commission, Directorate-General for Health and Food Safety, 2019. Final report of an audit carried out in France from 17 to 21 June 2019 to evaluate Member State activities to prevent tail-biting and avoid routine tail-docking of pigs (No. 2019-6603). https://ec.europa.eu/food/audits-analysis/audit-report/details/4245
European Commission Joint Research Centre, 2017. Best Available Techniques (BAT) reference document for the intensive rearing of poultry or pigs: Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). Publications Office, LU. https://data.europa.eu/doi/10.2760/020485
Ewald, C., Heer, A., Havenith, U., 1994. [Factors associated with the occurrence of influenza A virus infections in fattening swine]. Berl. Munch. Tierarztl. Wochenschr. 107, 256–262 (résumé en anglais : https://pubmed.ncbi.nlm.nih.gov/7945181/. Reste du texte en allemand).
Falke, A., Friedli, K., Gygax, L., Wechsler, B., Sidler, X., Weber, R., 2018. Effect of rubber mats and perforation in the lying area on claw and limb lesions of fattening pigs. Animal 12, 2130–2137. https://doi.org/10.1017/S175173111700341X
Fraser, D., 1985. Selection of bedded and unbedded areas by pigs in relation to environmental temperature and behaviour. Appl. Anim. Behav. Sci. 14, 117–126. https://doi.org/10.1016/0168-1591(85)90023-1
Fraser, D., Phillips, P.A., Thompson, B.K., Tennessen, T., 1991. Effect of straw on the behaviour of growing pigs. Appl. Anim. Behav. Sci. 30, 307–318. https://doi.org/10.1016/0168-1591(91)90135-K
Fritschen, R.D., 1979. Housing and its effect on feet and leg problems, in: Proc. Pig Vet. Soc. pp. 95–98.
Giorgetti, J., Robin, P., 2008. Eléments de comparaison du coût de revient et des émissions gazeuses de l'engraissement de porcs sur litière et sur caillebotis. http://www.porc-sur-paille.org/wp-content/uploads/2014/06/Etude-comparative-CR-porc-liti%C3%A8re-vs-caillebotis-Rapport-final-74p.pdf
Gómez-Prado, J., Pereira, A.M.F., Wang, D., Villanueva-García, D., Domínguez-Oliva, A., Mora-Medina, P., Hernández-Avalos, I., Martínez-Burnes, J., Casas-Alvarado, A., Olmos-Hernández, A., Ramírez-Necoechea, R., Verduzco-Mendoza, A., Hernández, A., Torres, F., Mota-Rojas, D., 2022. Thermoregulation mechanisms and perspectives for validating thermal windows in pigs with hypothermia and hyperthermia: An overview. Front. Vet. Sci. 9, 1023294. https://doi.org/10.3389/fvets.2022.1023294
Götz, M., Hilty, R., Herzog, D., 1992. Garde de porcs d'engraissement: porcheries à caillebotis partiel (Rapports FAT No. 413). Station fédérale de recherches d'économie d'entreprise et de géniie rural, Confédération suisse. https://link.ira.agroscope.ch/fr-CH/publication/17796
Gourmelen, C., Salaün, Y., Rousseau, P., 2001. Incidence économique, en production porcine, de l'évolution des contraintes réglementaires relatives au bien-être animal. Journ. Rech. Porc. 33, 325–331. https://www.journees-recherche-porcine.com/texte/2001/01txtBienetre/B0105.pdf
Granier, R., Guingand, N., Massabie, P., 1996. Influence du niveau d'hygrométrie, de la température et du taux de renouvellement de l'air sur l'évolution des teneurs en ammoniac. Journ. Rech. Porc. 209–216. https://www.journees-recherche-porcine.com/texte/1996/96txtLog/L9605.pdf
Gu, Z., Xin, H., Wang, Chaoyuan, Shi, Z., Liu, Z., Yang, F., Lin, B., Wang, Chao, Li, B., 2010. Effects of neoprene mat on diarrhea, mortality and foreleg abrasion of pre-weaning piglets. Prev. Vet. Med. 95, 16–22. https://doi.org/10.1016/j.prevetmed.2010.03.011
Guingand, N., 2003. Influence de la mise en place de caillebotis partiel et de la taille de la case sur les émissions d'ammoniac et d'odeurs en engraissement. Journ. Rech. Porc. 35, 15–20. https://www.journees-recherche-porcine.com/texte/2003/03txtEnv/e0303.pdf
Guingand, N., Courboulay, V., 2016. Effet du fractionnement des apports d'eau dans la technique du lisier flottant pour réduire les émissions d'ammoniac et d'odeurs en engraissement. Journ. Rech. Porc. 51, 181–186. https://www.journees-recherche-porcine.com/texte/2019/environnement/env03.pdf
Guingand, N., Granier, R., 2001. Comparaison caillebotis partiel et caillebotis intégral en engraissement. Journ. Rech. Porc. 33, 31–36. https://www.journees-recherche-porcine.com/texte/2001/01txtEnvlog/L0105.pdf

Guingand, N., Quiniou, N., Courboulay, V., 2010. Emissions comparées d'ammoniac et de gaz à effet de serre par des porcs charcutiers élevés au froid sur caillebotis partiel ou à la thermoneutralité sur caillebotis intégral. Journ. Rech. Porc. https://www.journees-recherche-porcine.com/texte/2010/env/En3.pdf

Guingand, N., Rousseliere, Y., Thomas, J., Collin, A., 2024. Agir sur la température ambiante pour réduire les émissions de NH3, N2O et CH4 d'une porcherie d'engraissement. Journ. Rech. Porc. 56, 395–400. https://www.journees-recherche-porcine.com/texte/2024/environnement/env01.pdf

Guy, J.H., Rowlinson, P., Chadwick, J.P., Ellis, M., 2002. Behaviour of two genotypes of growing–finishing pig in three different housing systems. Appl. Anim. Behav. Sci. 75, 193–206. https://doi.org/10.1016/S0168-1591(01)00197-6

Harley, S., More, S.J., O'Connell, N.E., Hanlon, A., Teixeira, D., Boyle, L., 2012. Evaluating the prevalence of tail biting and carcase condemnations in slaughter pigs in the Republic and Northern Ireland, and the potential of abattoir meat inspection as a welfare surveillance tool. Vet. Rec. 171, 621–621. https://doi.org/10.1136/vr.100986

Henry, M., Jansen, H., Amezcua, M. del R., O'Sullivan, T.L., Niel, L., Shoveller, A.K., Friendship, R.M., 2021. Tail-Biting in Pigs: A Scoping Review. Animals 11, 2002. https://doi.org/10.3390/ani11072002

Herskin, M., Jensen, K., Thodberg, K., 1999. Influence of environmental stimuli on nursing and suckling behaviour in domestic sows and piglets. Anim. Sci. 68, 27–34. https://doi.org/10.1017/S1357729800050049

Holm, L., Jensen, M., Pedersen, L., Ladewig, J., 2008. The importance of a food feedback in rooting materials for pigs measured by double demand curves with and without a common scaling factor. Appl. Anim. Behav. Sci. 111, 68–84. https://doi.org/10.1016/j.applanim.2007.05.013

Horback, K., McVey, C., Pierdon, M., 2021. Association patterns across multiple gestation cycles within a dynamic sow pen. Appl. Anim. Behav. Sci. 242. https://doi.org/10.1016/j.applanim.2021.105426

Hörning, B., 2007. Floor type, in: Velarde, A., Geers, R. (Eds.), On Farm Monitoring of Pig Welfare. Brill | Wageningen Academic, pp. 135–139. https://doi.org/10.3920/9789086865918_022

Hötzel, M., Lopes, E., de Oliveira, P., Guidoni, A., 2009. Behaviour and performance of pigs finished on deep bedding with wood shavings or rice husks in summer. Anim. Welf. 18, 65–71. https://doi.org/10.1017/S0962728600000075

Hukkinen, V.M., Munsterhjelm, C., Kurtti, M., Immonen, N., Valros, A., 2024. Impact of farrowing system and prepartum nest-building material on nest-building behaviour and farrowing in sows. Animal 18, 101183. https://doi.org/10.1016/j.animal.2024.101183

Hunter, E.J., Jones, T.A., Guise, H.J., Penny, R.H.C., Hoste, S., 2001. The Relationship Between Tail Biting in Pigs, Docking Procedure and Other Management Practices. Vet. J. 161, 72–79. https://doi.org/10.1053/tvjl.2000.0520

Hurnik, J.F., Webster, A.B., Siegel, P.B., 1999. Dictionnary of farm animal behavior. 2nd Edition. JF Hurnik (Eds) Iowa State University Press. Somerset, NJ.U.S.A.,1995.

Huynh, T., Aarnink, A., Spoolder, H., Verstegen, M. W. A., Kemp, B., 2004. Effects of floor cooling during high ambient temperatures on the lying behavior and productivity of growing finishing pigs. Trans. ASAE 47, 1773–1782. https://doi.org/10.13031/2013.17620

IFIP, 2019a. Fiche conseil "Porcisanté bâtiments et équipements" n°7 : Fondamentaux sur l'ambiance. https://ifip.asso.fr/app/uploads/2022/10/porci_bat-sept2022.zip

IFIP, 2019b. Fiche conseil "Porcisanté bâtiments et équipements" n°2 : Elevage sur paille : quelques points clés. https://ifip.asso.fr/app/uploads/2022/10/porci_bat-sept2022.zip

INERIS, 2018. Etat de l'art relatif aux meilleures techniques disponibles - Réduction des émissions d'ammoniac au niveau du stockage de lisier porcin dans les bâtiments (No. INERIS-DRC-17-163622-11651A). https://www.maisonbleue.fr/sites/default/files/webmaster/02-pdf/Rapport%20INERIS-%20MEILLEURES%20TECHNIQUES%20DISPONIBLES%20AU%20NIVEAU%20DU%20STOCKAGE%20DE%20LISIER%20PORCIN%20DRC-17-163622-11651A.pdf

Jean-Blain, C., 2002. Introduction à la nutrition des animaux domestiques, EMI. ed, Tec & Doc.

Jensen, M.B., Herskin, M.S., Forkman, B., Pedersen, L.J., 2015. Effect of increasing amounts of straw on pigs' explorative behaviour. Appl. Anim. Behav. Sci. 171, 58–63. https://doi.org/10.1016/j.applanim.2015.08.035
Jensen, M.B., Studnitz, M., Halekoh, U., Pedersen, L.J., Jørgensen, E., 2008. Pigs' preferences for rooting materials measured in a three-choice maze-test. Appl. Anim. Behav. Sci. 112, 270–283. https://doi.org/10.1016/j.applanim.2007.07.012
Jensen, P., 1989. Nest site choice and nest building of free-ranging domestic pigs due to farrow. Appl. Anim. Behav. Sci. 22, 13–21. https://doi.org/10.1016/0168-1591(89)90076-2
Jeppsson, K., Olsson, A., Nasirahmadi, A., 2021. Increased air velocity in the lying area improves pen hygiene and reduces ammonia emissions from houses with partly slatted pens for growing/finishing pigs. Livest. Sci. 251, 104607. https://doi.org/10.1016/j.livsci.2021.104607
Jørgensen, B., 2003. Influence of floor type and stocking density on leg weakness, osteochondrosis and claw disorders in slaughter pigs. Anim. Sci. 77, 439–449. https://doi.org/10.1017/S1357729800054382
Kelly, H.R.C., Bruce, J.M., English, P.R., Fowler, V.R., Edwards, S.A., 2000. Behaviour of 3-week weaned pigs in Straw-Flow®, deep straw and flatdeck housing systems. Appl. Anim. Behav. Sci. 68, 269–280. https://doi.org/10.1016/S0168-1591(00)00109-X
Kemppainen, E., 1987. Ammonia binding capacity of peat, straw, sawdust and cutter shavings. https://jukuri.luke.fi/handle/10024/471600
KilBride, A., Gillman, C., Green, L., 2009a. A cross-sectional study of the prevalence of lameness in finishing pigs, gilts and pregnant sows and associations with limb lesions and floor types on commercial farms in England. Anim. Welf. 18, 215–224. https://doi.org/10.1017/S0962728600000464
Kilbride, A., Gillman, C., Ossent, P., Green, L., 2009b. Impact of flooring on the health and welfare of pigs. In Pract. 31, 390-395. https://doi.org/10.1136/inpract.31.8.390
Kirkden, R.D., Broom, D.M., Andersen, I.L., 2013. INVITED REVIEW: Piglet mortality: Management solutions. J. Anim. Sci. 91, 3361–3389. https://doi.org/10.2527/jas.2012-5637
Lagadec, S., Landrain, B., Landrain, P., Ramonet, Y., Hassouna, M., Robin, P., 2013. Emissions d'ammoniac et de gaz à effet de serre en engraissement de porcs sur litière. https://bretagne.chambres-agriculture.fr/fileadmin/user_upload/National/FAL_commun/publications/Bretagne/PDF/Elevage/Porcs/Emissions_d_ammoniac_et_de_gaz_a_effet_de_serre_en_engraissement_de_porcs_sur_litiere.pdf
Lagoda, M.E., Boyle, L.A., Marchewka, J., Calderón Díaz, J.A., 2021. Mixing aggression intensity is associated with age at first service and floor type during gestation, with implications for sow reproductive performance. Animal 15, 100158. https://doi.org/10.1016/j.animal.2020.100158
Lahrmann, H.P., Hansen, C.F., D'Eath, R.B., Busch, M.E., Nielsen, J.P., Forkman, B., 2018. Early intervention with enrichment can prevent tail biting outbreaks in weaner pigs. Livest. Sci. 214, 272–277. https://doi.org/10.1016/j.livsci.2018.06.010
Lahrmann, H.P., Oxholm, L.C., Steinmetz, H., Nielsen, M.B.F., D'Eath, R.B., 2015. The effect of long or chopped straw on pig behaviour. Animal 9, 862–870. https://doi.org/10.1017/S1751731114003024
Larsen, M.L.V., Bertelsen, M., Pedersen, L.J., 2019. Pen Fouling in Finisher Pigs: Changes in the Lying Pattern and Pen Temperature Prior to Fouling. Front. Vet. Sci. 6. https://doi.org/10.3389/fvets.2019.00118
Larsen, M.L.V., Bertelsen, M., Pedersen, L.J., 2018. Review: Factors affecting fouling in conventional pens for slaughter pigs. ANIMAL 12, 322–328. https://doi.org/10.1017/S1751731117001586
Lawrence, A.B., Terlouw, E.M.C., 1993. A review of behavioral factors involved in the development and continued performance of stereotypic behaviors in pigs. J. Anim. Sci. 71, 2815–2825. https://doi.org/10.2527/1993.71102815x
Leeb, B., Leeb, C., Troxler, J., Schuh, M., 2001. Skin Lesions and Callosities in Group-Housed Pregnant Sows: Animal-Related Welfare Indicators. Acta Agric. Scand. Sect. Anim. Sci. 51, 82–87. https://doi.org/10.1080/090647001316923126

Lewis, E., Boyle, L.A., O'Doherty, J.V., Brophy, P., Lynch, P.B., 2005. The Effect of Floor Type in Farrowing Crates on Piglet Welfare. Ir. J. Agric. Food Res. 44, 69–81. http://www.jstor.org/stable/25562533

Lewis, E., Boyle, L.A., O'Doherty, J.V., Lynch, P.B., Brophy, P., 2006. The effect of providing shredded paper or ropes to piglets in farrowing crates on their behaviour and health and the behaviour and health of their dams. Appl. Anim. Behav. Sci. 96, 1–17. https://doi.org/10.1016/j.applanim.2005.04.015

Li, D., Zhang, K., Li, Z., Chen, Y., 2020. A Spatiotemporal Convolutional Network for Multi-Behavior Recognition of Pigs. Sensors 20, 2381. https://doi.org/10.3390/s20082381

Loussarn, A., Lagadec, S., Robin, P., Hassouna, M., 2014. Raclage en « V » : bilan environnemental et zootechnique lors de sept années de fonctionnement à Guernévez. Journ. Rech. Porc. 46, 199–204. https://www.maisonbleue.fr/sites/default/files/webmaster/02-pdf/telechargement/raclage_en_v-_bilan_environnemental_et_zootechnique_station_de_guernevez_-_2014%20%281%29.pdf

Lyons, C.A.P., Bruce, J.M., Fowler, V.R., English, P.R., 1995. A comparison of productivity and welfare of growing pigs in four intensive systems. Livest. Prod. Sci. 43, 265–274. https://doi.org/10.1016/0301-6226(95)00050-U

Mc Farland, D., 2006. A dictionnary of animal behaviour. Publisher Oxford university Press. 213p.

Madsen, A., 1980. Environmental influence on health of bacon pigs. Proceedings IPVS, Copenhagen. https://api.semanticscholar.org/CorpusID:68773291

Marcon, M., 2016. Les porcs ne manquent pas d'air. Tech Porc 31, 24–25. https://docs.ifip.asso.fr/pro/ils/DigitalCollection/DigitalCollectionAttachmentDownloadHandler.ashx?parentDocumentId=34794&documentId=39926

Markland, M.L., Gaskill, B.N., Johnson, J.S., Lay, D.C., 2020. PSI-16 Investigation of Jute to Stimulate Sow Nesting Behavior in Farrowing Crates. J. Anim. Sci. 98, 267. https://doi.org/10.1093/jas/skaa278.481

Martin-Houssart, G., 2010. Les bâtiments d'élevage porcin entre 2001 et 2008 - Les exploitations porcins aux normes européennes. Agreste Primeur 253 https://agreste.agriculture.gouv.fr/agreste-web/download/publication/publie/Pri253/primeur253.pdf

Matlova, L., Dvorska, L., Ayele, W.Y., Bartos, M., Amemori, T., Pavlik, I., 2005. Distribution of Mycobacterium avium Complex Isolates in Tissue Samples of Pigs Fed Peat Naturally Contaminated with Mycobacteria as a Supplement. J. Clin. Microbiol. 43, 1261–1268. https://doi.org/10.1128/jcm.43.3.1261-1268.2005

Merlot, E., Meunier-Salaun, M.-C., Peuteman, B., Pere, M.-C., Louveau, I., Perruchot, M.-H., Prunier, A., Gardan-Salmon, D., Gondret, F., Quesnel, H., 2022. Improving maternal welfare during gestation has positive outcomes on neonatal survival and modulates offspring immune response in pigs. Physiol. Behav. 249, 113751. https://doi.org/10.1016/j.physbeh.2022.113751

Meunier-Salaün, M. C., Bolhuis, J. E., 2014. 5. High-Fibre feeding in gestation, in: The Gestating and Lactating Sow. Wageningen Academic Publishers, pp. 95–116. https://doi.org/10.3920/978-90-8686-803-2_5

Meunier-Salaün, M.C., Bizeray, D., Colson, V., Courboulay, V., Lensink, J., Prunier, A., Remience, V., Vandenheede, M., 2007. Bien-être et élevage des porcs. INRAE Prod. Anim. 20, 73–80. https://doi.org/10.20870/productions-animales.2007.20.1.3438

Ministère de l'agriculture et de l'alimentation, 2020. Arrêté du 17 novembre 2021 modifiant l'arrêté du 24 février 2020 modifiant l'arrêté du 16 janvier 2003 établissant les normes minimales relatives à la protection des porcs.

Moinard, C., Mendl, M., Nicol, C.J., Green, L.E., 2003. A case control study of on-farm risk factors for tail biting in pigs. Appl. Anim. Behav. Sci. 81, 333–355. https://doi.org/10.1016/S0168-1591(02)00276-9

Morgan, C.A., Deans, L.A., Lawrence, A.B., Nielsen, B.L., 1998. The effects of straw bedding on the feeding and social behaviour of growing pigs fed by means of single-space feeders. Appl. Anim. Behav. Sci. 58, 23–33. https://doi.org/10.1016/S0168-1591(97)00141-X

Mormède, P., Foury, A., Meunier-Salaün, M.-C., 2006. Bien-être du porc : le point de vue de l'animal, approches biologiques et comportementales. Bull. Académie Vét. Fr. 159, 191–204. https://doi.org/10.4267/2042/47833
Morrison, R.S., Johnston, L.J., Hilbrands, A.M., 2007. The behaviour, welfare, growth performance and meat quality of pigs housed in a deep-litter, large group housing system compared to a conventional confinement system. Appl. Anim. Behav. Sci. 103, 12–24. https://doi.org/10.1016/j.applanim.2006.04.002
Mouttotou, N., Green, L.E., Hatchell, F.M., 1998. Adventitious bursitis of the hock in finishing pigs: prevalence, distribution and association with floor type and foot lesions. Vet. Rec. 142, 109–114. https://doi.org/10.1136/vr.142.5.109
Mouttotou, N., Hatchell, F.M., Green, L.E., 1999. Prevalence and risk factors associated with adventitious bursitis in live growing and finishing pigs in south-west England. Prev. Vet. Med. 39, 39–52. https://doi.org/10.1016/S0167-5877(98)00141-X
Munsterhjelm, C., Heinonen, M., Valros, A., 2015. Application of the Welfare Quality® animal welfare assessment system in Finnish pig production, part II: Associations between animal-based and environmental measures of welfare. Anim. Welf. 24, 161–172. https://doi.org/10.7120/09627286.24.2.161
Munsterhjelm, C., Peltoniemi, O.A.T., Heinonen, M., Hälli, O., Karhapää, M., Valros, A., 2009. Experience of moderate bedding affects behaviour of growing pigs. Appl. Anim. Behav. Sci. 118, 42–53. https://doi.org/10.1016/j.applanim.2009.01.007
Nannoni, E., Aarnink, A.J.A., Vermeer, H.M., Reimert, I., Fels, M., Bracke, M.B.M., 2020. Soiling of Pig Pens: A Review of Eliminative Behaviour. Animal 10, 2025. https://doi.org/10.3390/ani10112025
Näslund, J., Johnsson, J.I., 2016. Environmental enrichment for fish in captive environments: effects of physical structures and substrates. Fish & Fisheries 17, 1–30. https://doi.org/10.1111/faf.12088
Newberry, R.C., 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Appl. Anim. Behav. Sci. 44, 229–243. https://doi.org/10.1016/0168-1591(95)00616-Z
Nielsen, B.L., Lawrence, A.B., Whittemore, C.T., 1995. Effect of group size on feeding behaviour, social behaviour, and performance of growing pigs using single-space feeders. Livest. Prod. Sci. 44, 73–85. https://doi.org/10.1016/0301-6226(95)00060-X
Nielsen, E.O., Hassing, A.G., Wachmann, H., Baekbo, P., Petersen, H.H., Nielsen, J.P., 2002. Associations between housing system, management and lameness in slaughter pigs. In: . Ames, Iowa, USA, 2-5 June 2002, in: 17th International Pig Veterinary Society Congress. Ames, Iowa, USA. https://researchprofiles.ku.dk/en/publications/associations-between-housing-system-management-and-lameness-in-sl
Nollet, N.D., Maes, D., De Zutter, L., Duchateau, L., Houf, K., Huysmans, K., Imberechts, H., Geers, R., de Kruif, A., Van Hoof, J., 2004. Risk factors for the herd-level bacteriologic prevalence of Salmonella in Belgian slaughter pigs. Prev. Vet. Med. 65, 63–75. https://doi.org/10.1016/j.prevetmed.2004.06.009
Ocepek, M., Andersen, I.L., 2022. The Effects of Pen Size and Design, Bedding, Rooting Material and Ambient Factors on Pen and Pig Cleanliness and Air Quality in Fattening Pig Houses. Animals 12. https://doi.org/10.3390/ani12121580
Paboeuf, F., Gautier, M., Cariolet, R., Ramonet, Y., Dourmad, J.-Y., 2009. Effet de la surface, de la nature du sol et du mode d'alimentation sur les performances zootechniques et la production d'effluents des porcs en croissance. Journ. Rech. Porc. 209–216. https://www.journees-recherche-porcine.com/texte/2009/conduite/be02.pdf
Pedersen, L.J., Herskin, M.S., Forkman, B., Halekoh, U., Kristensen, K.M., Jensen, M.B., 2014. How much is enough? The amount of straw necessary to satisfy pigs' need to perform exploratory behaviour. Appl. Anim. Behav. Sci. 160, 46–55. https://doi.org/10.1016/j.applanim.2014.08.008
Pedersen, L.J., Larsen, M.L.V., Malmkvist, J., 2016. The ability of different thermal aids to reduce hypothermia in neonatal piglets. J. Anim. Sci. 94, 2151–2159. https://doi.org/10.2527/jas.2015-0219

Pedersen, L.J., Malmkvist, J., Andersen, H.M.L., 2015. Housing of sows during farrowing: a review on pen design, welfare and productivity, in: Aland, A., Banhazi, T. (Eds.), Livestock Housing. Brill | Wageningen Academic, pp. 93–112. https://doi.org/10.3920/978-90-8686-771-4_05
Phillips, Fraser, Pawluczuk, 1995. Effects of Cushioned Flooring on Piglet Leg Injuries. Trans. ASAE 38, 213–216. https://doi.org/10.13031/2013.27832
Phillips, P.A., Pawluczuk, B., 1995. A floor overlay for reducing leg abrasion injuries on piglets. Can. Agric. Eng. https://library.csbe-scgab.ca/docs/journal/37/37_3_231_ocr.pdf
Pouteaux, V.A., Christison, G.I., Stricklin, W.R., 1983. Perforated-floor preference of weanling pigs. Appl. Anim. Ethol. 11, 19–23. https://doi.org/10.1016/0304-3762(83)90075-5
Prunier, A., Devillers, N., Herskin, M. s., Sandercock, D. a., Sinclair, A. r. l., Tallet, C., von Borell, E., 2019. 4. Husbandry interventions in suckling piglets, painful consequences and mitigation, in: The Suckling and Weaned Piglet. Wageningen Academic Publishers, pp. 107–138. https://doi.org/10.3920/978-90-8686-894-0_4
Ramonet, Y., Bertin, C., Kergoulay, F., Villain, N., 2018a. Truies libres en maternité. Terra. https://opera-connaissances.chambres-agriculture.fr/doc_num.php?explnum_id=103154
Ramonet, Y., Bertin, C., Villain, N., Caille, M.-E., Dubois, A., Meunier-Salaün, M.-C., 2018b. Les truies libres en maternité: modalités de logement et de conduite, performances, conditions de travail et bien-être. Chambres d'Agriculture de Bretagne. https://hal.science/hal-01985343
Ramonet, Y., Chiron, J., Etore, F., Laval, A., Nielsen, B., Pol, F., Prunier, A., Meunier-Salaün, M.-C., 2017. Abreuvement des porcs : état des connaissances et conséquences sur le bien-être des animaux et la gestion des effluents chez des porcs alimentés en soupe. Journ. Rech. Porc. 49, 139–150. https://www.journees-recherche-porcine.com/texte/2017/bienetre/B03.pdf
Ramonet, Y., Le Gac, M., Giteau, J.L., 2015. Typologie des exploitations qui détiennent des porcs sur litière en Bretagne. https://opera-connaissances.chambres-agriculture.fr/doc_num.php?explnum_id=172312
Ramonet, Y., Villain, N., 2021. Élevage de porcs à queue entière sur litière. Effet de la génétique mâle Duroc et Piétrain sur les performances et l'état des queues, Chambres d'agriculture de Bretagne. ed. https://www.researchgate.net/publication/350545570
Rantzer, D., Svendsen, J., 2001. Slatted versus Solid Floors in the Dung Area: Comparison of Pig Production System (Moved versus not Moved) and Effects on Hygiene and Pig Performance, Weaning to Four Weeks after Weaning. Acta Agric Scand Sect Anim. Sci 51, 175–183. https://doi.org/10.1080/09064700120126
Rault, J.-L., 2019. Be kind to others: Prosocial behaviours and their implications for animal welfare. Appl. Anim. Behav. Sci. 210, 113–123. https://doi.org/10.1016/j.applanim.2018.10.015
Réussir Porc, 2024. Effet limité des tapis en gestation sur les troubles locomoteurs des truies [WWW Document], 2019. URL https://www.reussir.fr/porc/effet-limite-des-tapis-en-gestation-sur-les-troubles-locomoteurs (consulté le 18/09/24).
Riedel, A., Pieper, L., Lautner, M., Leiding, C., Jung, M., Schulze, M., 2024. Influence of deep-litter bedding materials on environmental and welfare-related factors in boar studs. Appl. Anim. Behav. Sci. 273, 106215. https://doi.org/10.1016/j.applanim.2024.106215
RMT Elevage et Environnement, 2019. Guide des bonnes pratiques environnementales d'élevage. Fiche P12 Logement sur litière. https://www.rmtelevagesenvironnement.org/docs/fiches/gbpee/porc/p-fiche-12.pdf
Roepstorff, A., Jorsal, S.E., 1990. Relationship of the prevalence of swine helminths to management practices and anthelmintic treatment in Danish sow herds. Vet. Parasitol. 36, 245–257. https://doi.org/10.1016/0304-4017(90)90036-B
Rosvold, E.M., Andersen, I.-L., 2019. Straw vs. peat as nest-building material – The impact on farrowing duration and piglet mortality in loose-housed sows. Livest. Sci. 229, 203–209. https://doi.org/10.1016/j.livsci.2019.05.014
Rosvold, E.M., Newberry, R.C., Andersen, I.L., 2019. Early mother-young interactions in domestic sows – Nest-building material increases maternal investment. Appl. Anim. Behav. Sci. 219, 104837. https://doi.org/10.1016/j.applanim.2019.104837

Rosvold, E.M., Newberry, R.C., Framstad, T., Andersen, I.-L., 2018. Nest-building behaviour and activity budgets of sows provided with different materials. Appl. Anim. Behav. Sci. 200, 36–44. https://doi.org/10.1016/j.applanim.2017.12.003

Rousseliere, Y., 2024. Evolution des coûts à la place et des bâtiments porcins entre 2015 et 2023. Poster présenté au Colloque BOW, Rennes. https://ifip.asso.fr/documentations/46165-evolution-des-couts-a-la-place-et-des-batiments-porcins-entre-2015-et-2023/

Ruckli, A. K., Hörtenhuber, S., Dippel, S., Ferrari, P., Gebska, M., Heinonen, M., Helmerichs, J., Hubbard, C., Spoolder, H., Valros, A., Winckler, C., Leeb, C., 2024. Access to bedding and outdoor runs for growing-finishing pigs: is it possible to improve welfare without increasing environmental impacts? Animal 18, 101155. https://doi.org/10.1016/j.animal.2024.101155

Ruckli, A.K., Hörtenhuber, S., Dippel, S., Ferrari, P., Gebska, M., Heinonen, M., Helmerichs, J., Hubbard, C., Spoolder, H., Valros, A., Winckler, C., Leeb, C., 2024. Access to bedding and outdoor runs for growing-finishing pigs: is it possible to improve welfare without increasing environmental impacts? Animal 18, 101155. https://doi.org/10.1016/j.animal.2024.101155

Salaün, C., Callarec, J., Toudic, M., 2002. Effet du type de sol sur le bien-être des truies gestantes en groupe alimentées au Distributeur Automatique de Concentré (DAC). Journ. Rech. Porc. 34, 216–223. https://www.journees-recherche-porcine.com/texte/2002/02txtBienetre/BE0203.pdf

Savary, P., Hauser, R., Wechsle, B., 2008. Emploi de tapis en plastique dans l'aire de repos des porcs à l'engrais - Effets positifs sur le comportement des animaux au repos ainsi que sur les dommages constatés sur leurs membres (No. 684), Rapports ART. Département fédéral de l'économie, Confédération suisse. https://ira.agroscope.ch/en-US/publication/17838

Schaefer, A.L., Salomons, M.O., Tong, A.K.W., Sather, A.P., Lepage, P., 1990. The effect of environment enrichment on aggression in newly weaned pigs. Appl. Anim. Behav. Sci. 27, 41–52. https://doi.org/10.1016/0168-1591(90)90006-Y

Scollo, A., Contiero, B., Gottardo, F., 2016. Frequency of tail lesions and risk factors for tail biting in heavy pig production from weaning to 170 kg live weight. Vet. J. 207, 92–98. https://doi.org/10.1016/j.tvjl.2015.10.056

Scollo, A., Di Martino, G., Bonfanti, L., Stefani, A.L., Schiavon, E., Marangon, S., Gottardo, F., 2013. Tail docking and the rearing of heavy pigs: the role played by gender and the presence of straw in the control of tail biting. Blood parameters, behaviour and skin lesions. Res. Vet. Sci. 95, 825–830. https://doi.org/10.1016/j.rvsc.2013.06.019

Scott, K., Chennells, D.J., Campbell, F., Hunt, B., Armstrong, D., Taylor, L., Gill, B., Edwards, S., 2006. The welfare of finishing pigs in two contrasting housing systems: Fully-slatted versus straw-bedded accommodation. Livest. Sci. 103, 104–115. https://doi.org/10.1016/j.livsci.2006.01.008

Scott, K., Taylor, L., Gill, B.P., Edwards, S.A., 2007. Influence of different types of environmental enrichment on the behaviour of finishing pigs in two different housing systems. Appl. Anim. Behav. Sci. 105, 51–58. https://doi.org/10.1016/j.applanim.2006.05.042

Skjerve, E., Lium, B., Nielsen, B., Nesbakken, T., 1998. Control of Yersinia enterocolitica in pigs at herd level. Int. J. Food Microbiol. 45, 195–203. https://doi.org/10.1016/S0168-1605(98)00162-7

Spoolder, H., 2002. Pens for finishing pigs with 60% solid floor area. Wageningen U R. https://edepot.wur.nl/34313

Spoolder, H., Bracke, M., Mueller-Graf, C., Edwards, S., 2011. Preparatory work for the future development of animal based measures for assessing the welfare of pig - Report 2: Preparatory work for the future development of animal based measures for assessing the welfare of weaned, growing and fattening pigs including aspects related to space allowance, floor types, tail biting and need for tail docking. EFSA Support. Publ. 8. https://doi.org/10.2903/sp.efsa.2011.EN-181

Spoolder, H.A.M., Edwards, S.A., Corning, S., 2000. Legislative methods for specifying stocking density and consequences for the welfare of finishing pigs. Livest. Prod. Sci. 64, 167–173. https://doi.org/10.1016/S0301-6226(99)00152-9

SRDP Farm Advisory Service, 2024. Alternative Bedding Materials. https://www.fas.scot/downloads/alternative-bedding-materials/

Stolba, A., Wood-Gush, D.G.M., 1989. The behaviour of pigs in a semi-natural environment. Anim. Sci. 48, 419–425. https://doi.org/10.1017/S0003356100040411

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. Appl. Anim. Behav. Sci. 107, 183–197. https://doi.org/10.1016/j.applanim.2006.11.013

Swan, K.-M., Peltoniemi, O.A.T., Munsterhjelm, C., Valros, A., 2018. Comparison of nest-building materials in farrowing crates. Appl. Anim. Behav. Sci. 203, 1–10. https://doi.org/10.1016/j.applanim.2018.02.008

Tallet, C., Rakotomahandry, M., Herlemont, S., Prunier, A., 2019. Evidence of Pain, Stress, and Fear of Humans During Tail Docking and the Next Four Weeks in Piglets (Sus scrofa domesticus). Front. Vet. Sci. 6, 462. https://doi.org/10.3389/fvets.2019.00462

Taylor, P.S., Schrobback, P., Verdon, M., Lee, C., 2023. An effective environmental enrichment framework for the continual improvement of production animal welfare. Anim. Welf. 32, e14. https://doi.org/10.1017/awf.2023.5

Telkänranta, H., Bracke, M.B.M., Valros, A., 2014. Fresh wood reduces tail and ear biting and increases exploratory behaviour in finishing pigs. Appl. Anim. Behav. Sci. 161, 51–59. https://doi.org/10.1016/j.applanim.2014.09.007

Temple, D., Courboulay, V., Velarde, A., Dalmau, A., Manteca, X., 2012. The welfare of growing pigs in five different production systems in France and Spain: assessment of health. Anim. Welf. 21, 257–271. https://doi.org/10.7120/09627286.21.2.257

Trickett, S.L., Guy, J.H., Edwards, S.A., 2009. The role of novelty in environmental enrichment for the weaned pig. Appl. Anim. Behav. Sci. 116, 45–51. https://doi.org/10.1016/j.applanim.2008.07.007

Tuyttens, F.A.M., 2005. The importance of straw for pig and cattle welfare: A review. Appl. Anim. Behav. Sci. 92(3), 261–282. https://doi.org/10.1016/j.applanim.2005.05.007

Valros, A., 2022. Review: The tale of the Finnish pig tail - how to manage non-docked pigs? Animal 16. https://doi.org/10.1016/j.animal.2021.100353

Valros, A., Munsterhjelm, C., Hänninen, L., Kauppinen, T., Heinonen, M., 2016. Managing undocked pigs – on-farm prevention of tail biting and attitudes towards tail biting and docking. Porc. Health Manag. 2, 2. https://doi.org/10.1186/s40813-016-0020-7

Valros, A., Välimäki, E., Nordgren, H., Vugts, J., Fàbrega, E., Heinonen, M., 2020. Intact Tails as a Welfare Indicator in Finishing Pigs? Scoring of Tail Lesions and Defining Intact Tails in Undocked Pigs at the Abattoir. Front. Vet. Sci. 7, 405. https://doi.org/10.3389/fvets.2020.00405

Van de Weerd, H.A., Day, J.E.L., 2009. A review of environmental enrichment for pigs housed in intensive housing systems. Appl. Anim. Behav. Sci. 116, 1–20. https://doi.org/10.1016/j.applanim.2008.08.001

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Avery, P.J., Edwards, S.A., 2003. A systematic approach towards developing environmental enrichment for pigs. Appl. Anim. Behav. Sci. 84, 101–118. https://doi.org/10.1016/S0168-1591(03)00150-3

Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Breuer, K., Edwards, S.A., 2006. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. Appl. Anim. Behav. Sci. 99, 230–247. https://doi.org/10.1016/j.applanim.2005.10.014

Van Grevenhof, E.M., Ott, S., Hazeleger, W., van Weeren, P.R., Bijma, P., Kemp, B., 2011. The effects of housing system and feeding level on the joint-specific prevalence of osteochondrosis in fattening pigs. Livest. Sci. 135, 53–61. https://doi.org/10.1016/j.livsci.2010.06.010

Van Putten, G.V., 1980. Objective observations on the behaviour of fattening pigs. Anim. Regul. Stud. 3.

Van Staaveren, N., Boyle, L.A., Manzanilla, E.G., O'Driscoll, K., Shalloo, L., Díaz, J.A.C., 2021. Severe tail lesions in finisher pigs are associated with reduction in annual profit in farrow-to-finish pig farms. Vet. Rec. 188, e13. https://doi.org/10.1002/vetr.13

Vanheukelom, V., Driessen, B., Geers, R., 2012. The effects of environmental enrichment on the behaviour of suckling piglets and lactating sows: A review. Livest. Sci. 143, 116–131. https://doi.org/10.1016/j.livsci.2011.10.002

Veissier, I., Lesimple, C., Brunet, V., Aubé, L., Botreau, R., 2024. Review: Rethinking environmental enrichment as providing opportunities to acquire information. Animal 18, 101251. https://doi.org/10.1016/j.animal.2024.101251

Vermeij, I., Enting, J., Spoolder, H. a. M., 2009. Effect of slatted and solid floors and permeability of floors in pig houses on environment, animal welfare and health and food safety: a review of literature. Animal Sciences Group. https://edepot.wur.nl/1600

Wachenfelt, H. von, Pinzke, S., Nilsson, C., Olsson, O., Ehlorsson, C.-J., 2008. Gait analysis of unprovoked pig gait on clean and fouled concrete surfaces. Biosyst. Eng. 101, 376–382. https://doi.org/10.1016/j.biosystemseng.2008.09.002

Wallgren, T., Gunnarson, S., 2022. Implementation of Straw Racks in Commercial Pig Housing-Impact on Straw Availability and Pig Behaviour. Agric.-BASEL 12, 5. https://doi.org/10.3390/agriculture12010005

Wallgren, T., Larsen, A., Lundeheim, N., Westin, R., Gunnarsson, S., 2019. Implication and impact of straw provision on behaviour, lesions and pen hygiene on commercial farms rearing undocked pigs. Appl. Anim. Behav. Sci. 210, 26–37. https://doi.org/10.1016/j.applanim.2018.10.013

Wallgren, T., Lundeheim, N., Gunnarsson, S., 2020. Impact of amount of straw on pig and pen hygiene in partly slatted flooring systems. BMC Vet. Res. 16, 377. https://doi.org/10.1186/s12917-020-02594-y

Welfarm, 2015. Des porcs, des élevages, des litières - Des éleveurs témoignent. https://objectif-litiere.fr/wp-content/uploads/2015/06/guide-porcs-welfarm-2015.pdf

Westin, R., Holmgren, N., Mattsson, B., Algers, B., 2013. Throughput capacity of large quantities of chopped straw in partly slatted farrowing pens for loose housed sows. Acta Agric. Scand. Sect. - Anim. Sci. 63, 18–27. https://doi.org/10.1080/09064702.2013.780633

Wood-Gush, D.G.M., Beilharz, R.G., 1983. The enrichment of a bare environment for animals in confined conditions. Appl. Anim. Ethol. 10, 209–217. https://doi.org/10.1016/0304-3762(83)90142-6

Wood-Gush, D.G.M., Vestergaard, K., 1991. The seeking of novelty and its relation to play. Anim. Behav. 42, 599–606. https://doi.org/10.1016/S0003-3472(05)80243-X

Young, C., 2019. Agonistic Behavior, in: Vonk, J., Shackelford, T. (Eds.), Encyclopedia of Animal Cognition and Behavior. Springer, Cham, pp. 1–6. https://doi.org/10.1007/978-3-319-47829-6_320-1

Yun, J., Swan, K.-M., Farmer, C., Oliviero, C., Peltoniemi, O., Valros, A., 2014. Prepartum nest-building has an impact on postpartum nursing performance and maternal behaviour in early lactating sows. Appl. Anim. Behav. Sci. 160, 31–37. https://doi.org/10.1016/j.applanim.2014.08.011

Yun, J., Valros, A., 2015. Benefits of Prepartum Nest-building Behaviour on Parturition and Lactation in Sows - A Review. Asian-Australas. J. Anim. Sci. 28, 1519–1524. https://doi.org/10.5713/ajas.15.0174

Zonderland, J.J., Wolthuis-Fillerup, M., van Reenen, C.G., Bracke, M.B.M., Kemp, B., Hartog, L.A. den, Spoolder, H.A.M., 2008. Prevention and treatment of tail biting in weaned piglets. Appl. Anim. Behav. Sci. 110, 269–281. https://doi.org/10.1016/j.applanim.2007.04.005

Zwicker, B., Gygax, L., Wechsler, B., Weber, R., 2013. Short- and long-term effects of eight enrichment materials on the behaviour of finishing pigs fed ad libitum or restrictively. Appl. Anim. Behav. Sci. 144, 31–38. https://doi.org/10.1016/j.applanim.2012.11.007

Zwicker, B., Gygax, L., Wechsler, B., Weber, R., 2012. Influence of the accessibility of straw in racks on exploratory behaviour in finishing pigs. Livest. Sci. 148, 67–73. https://doi.org/10.1016/j.livsci.2012.05.008

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