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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

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Abstract
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Keywords: pigs, housing, floor type, permeability

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Contents

Abstract

Floor design in pig pens should be optimal for the welfare of the animals and should prevent pen fouling. Factors to be taken into account when optimizing floors are the total space and space per animal, the gap and slat width and the ratio solid: slatted area. An extensive literature review on those aspects and the quality of the floor was carried out by the European Food Safety Authority (EFSA, 2005). The EFSA used a risk assessment approach and they principally concerned with aspects of housing and management. In the EFSA report floor designs in pig housing have been analyzed in general by a single factor approach. The combined effects of gap width, slat width, use of solid floors and maximum drainage openings in solid floors were not brought up, though those combined effects are important for animal welfare, health and food safety. Therefore in this literature review an integrated approach is introduced in which individual aspects are brought together. This review also introduces the factor of 'permeability of the total floor area', which equals the percentage of floor which is permeable. Floor quality was assessed by looking at effects on the environment, welfare & health of the animal and salmonella contamination. The factors describing a floor were the percentage of solid floor, the percentage of drainage openings in the solid floor, the gap width and the slat width. Floor designs were generally subdivided into four categories with increasing percentage of solid floor:

- I Fully slatted floor
- II <40% solid floor
- III 40% concrete solid floor, 60% slatted floor with gap width 18 mm (Reference)
- IV >40% solid floor

Information from the references for the different categories has been collected in a spreadsheet (Appendix A) and are described in this review. The expectation was that the various aspects of an optimal floor design could be integrated and that this could be expressed in an equation which included proportion of solid floor, drainage openings of the solid floor, gap and slat width. Initially the effects of floor factors on separate aspects were analyzed.

Effect of floor type on the environmental aspects
Different authors have investigated environmental impacts, mainly through pen fouling and ammonia emission. To prevent pen fouling through obstructed gaps there have to be sufficient drainage openings and it is necessary to look at the total permeability. Extrapolation of data in the references suggests there has to be a minimum of about 12.5% permeability for optimal drainage. The Reference floor has a permeability of 9%.

Effect of floor type on animal health and welfare
A number of authors have investigated the clinical symptoms and claw problems in relation to flooring aspects. The effects appear contradictory sometimes, with different floor types showing different effects on different health aspects. Gaps which are too big may lead to claw problems. Fully slatted floors lead to a higher risk of lameness than partly solid floors and the prevalence of bursitis was higher. In contrast, fully slatted floors were associated with lower risk of disease.

Influence of floor type on salmonella
A few authors have investigated the prevalence of salmonella on different floor types and conclude that the risk for salmonella was lowest at fully slatted floors.

Integrated approach
An integrated approach can improve understanding of floor performance. Not only gap width or percentage of slatted floor is important, but a minimum percentage of permeability of the total floor area appears to be decisive. Seufert et al. (1980) showed that on a fully slatted floor with a permeability of 8% there are 25% blocked gaps, whereas with a permeability of 14% there are hardly any blocked gaps.
The aim of this study was to describe a model for integrated effects of floor factors. This proved impossible with the data currently available: the situation in each of the references studied differed too much. Therefore a representation with red (negative) and green (positive) colors was chosen. Compared with >40% solid floor a fully slatted floor is positive for the topics pen fouling, bacterium, health, claw problems and salmonella. On the other hand fully slatted floor is negative for claw injuries, lameness, claw defects and prevalence of bursitis.
Good permeability of floors in pig pens is essential in relation to environmental aspects (especially pen fouling), animal health and welfare and to prevent salmonella, but in literature permeability is seldom investigated. Fully slatted floors have generally a higher percentage of permeability (20%) than (partly) solid floors. Aarnink et al. (1993) suggested a permeability of 12.5% of the total floor to prevent pen fouling. It is recommended that to define the optimal floor, data should be collected from many different situations in a systematic way. This will then allow analyses and description of the interaction of different flooring factors on environmental and welfare issues.

1 Introduction

The Dutch Product Board for Livestock and Meat asked the Animal Sciences Group from Wageningen UR to analyze the available knowledge on the effects of the proportion of solid floor and the permeability of floors on animal welfare, animal health, the environment and food safety.
Floor design in pig pens should be optimal for the welfare and health of the animals and should prevent pen fouling to reduce ammonia emission and labour and to benefit food safety. On an optimal floor there is minimal contact between excrement and animal, there is minimal emitting surface, there is low risk of claw lesions and the floor provides a comfortable lying space. Factors affecting for the quality of the floor are the total space and space per animal, the gap width, slat width, the ratio solid area : slatted area and the permeability of the floor. An extensive literature study on minimum floor area, part of solid floor, gap and slat width and quality of floor was carried out by the European Food Safety Authority (EFSA, 2005). In addition to animal welfare aspects, EFSA took into account health aspects and food safety aspects. EFSA used a risk assessment approach. Although many factors affect the risk of poor welfare in pigs, this study was principally concerned with certain aspects of housing and management. They described the needs and functioning of pigs in relation to effects of flooring and space allowances and described the current housing systems and types of flooring used in pig production in the EU countries. Floor effects included were slatted and solid floor, gap width and slat width and material of the slats. In the EFSA study the effects of these floor aspects on air quality, mobility and injuries, diseases and carcass and food safety were summarized. The results and conclusions about these floor aspects were not unambiguous, e.g. for pen fouling gap width has another optimum in comparison to claw injuries. The different references in the EFSA report investigated floor designs in pig housing in general by a single factor approach. For example they looked separately into the effects of gap width on pen fouling and into the effects of slat width on pen fouling. The combined effects of gap width, slat width, use of solid floors and maximum drainage openings in solid floors were not investigated, though those combined effects are important for animal welfare, health and food safety. Especially for pen fouling there is a relationship between claw and leg problems in pigs and food born diseases for humans and therefore the total permeability of the floor is essential.

The separate and combined effects are also relevant in relation to European and national legislation. There are large differences in floor quality and quantity requirements between EU member states. Council Directive 91/630/EEC, as amended by 2001/88/EC and 2001/93/EC, laying down minimum standards for the protection of pigs include requirements for the proportion of solid floor and the maximum of drainage openings, gap width and slat width. Enting et al. (2006) investigated how these directives are implemented in a number of European countries.
The EU Directive prescribes some solid floor for gilts after service and pregnant sows, but the Netherlands and Denmark also describe some solid floor for weaned piglets and rearing pigs. The Netherlands requires for rearing pigs 40% solid floor and for weaned piglets 40% solid floor when concrete floor is used. Denmark legislates for weaned piglets and rearing pigs 50% and 33% solid floor respectively. Germany wants 50% solid floor for rearing pigs and gilts (Tierschutz-Nutztierhaltungsverordnung, 2006). The EU allows 15% of drainage openings in solid floor, Denmark allows 10% and the Netherlands allows only 5% drainage openings. For gap width most countries follow the EU-directive, but the Netherlands have legislated for smaller gap width for piglets (10 mm instead of 11 mm) and Denmark applies the EU-requirement only to fully slatted floors.
The EU countries translate and interpret the EU Directive differently, which can lead to an imbalance in the level playing field for different countries. As long as the influence from a combination of different requirements on animal welfare and health is not fully understood and we do not know exactly what the effects on food safety and environment are, the relative merits and demerits from this imbalance cannot be visualized. Obviously the share of solid floor, the permeability of this solid floor and the gap and slat width of the slatted floor are playing a part in this. Only an integrated approach of those requirements can help to develop better floor concepts.
Therefore the present literature review attempted another route by bringing together the separate factors into an integrated analyses of the impacts on health, welfare and the environment. As permeability of the total floor area is important in this respect, this aspect was brought in as well.

2 Materials and Methods

The study focused on three topics in relation to the effects of solid floor, drainage openings, gap width and slat width. These topics were environment, welfare & health and salmonella (food safety).

Starting point for the welfare topic was the report of the European Food Safety Authority (EFSA, 2005). This report described the effects of different floor area and floor types on the welfare of weaned piglets and rearing pigs and contains information from almost 600 references. These references and their conclusions were used for the welfare part of this study and other (newer) references were added if appropriate. In general, the references only described a single approach to requirements for floor design, where an integrated approach would be needed to develop optimal floor design. Further more, the different references describe a wide variety of methods that they have used on a wide variety of floor concepts. To facilitate interpretation of the data, in the present study a categorical division was made and each system described in a reference was allocated to a category of flooring based on the percentage of solid floor. See Appendix A.

Categorical division
Four categories with increasing percentage of solid floor were made:
- I Fully slatted floor
- II <40% solid floor
- III 40% concrete solid floor, 60% slatted floor with gap width 18 mm (Reference)
- IV >40% solid floor

These floors differ in the permeability. Permeability is here defined in a quantitative way as the percentage of surface of drainage openings compared with total surface. In generally fully slatted floors have 20% permeability. The reference reflects the standard situation for rearing pigs from 25 kg in the Netherlands. The percentages of permeability in this paper are not described in the literature, but were estimated based on the slat and gap width, percentage of slatted and solid floor and the presence (or absence) of a dunging gap (along the back wall). The term 'permeability' in this report is also used in a qualitative way, meaning how (good, bad) the floor allow to pass manure and urine.
Information from the references for the different categories was collected in a spreadsheet (see Appendix A) and are described in this review. The single aspects which were described are environmental aspects (pen fouling, ammonia emission), animal health and welfare and salmonella. In the spreadsheet the author, year of publication and outcome of the research are listed.
Secondly an approach to integrate the flooring factors into a single model was described.
The expectation was that, based on the EFSA report which brought together information of almost 600 references, the various aspects of an optimal floor design can be integrated. This integration should allow the analyses of effects on ammonia emission, pen fouling, lameness, salmonella infections and other health problems in relation to total permeability of the floor. The model can be described in an equation which includes proportion of solid floor, drainage openings of the solid floor, gap width and slat width.

Y = α * solid floor (% of total) + β * gap width (mm) + γ * slat width (mm) + drainage openings (% of solid) + error.

Y can be the extent of pen fouling or lameness or prevalence of diseases, for example. In this way the optimal combination for different factors can be found.

3 Influence of floor type on the environmental aspects

Different authors have investigated the topics pen fouling and ammonia emission in relation to floor quality parameters. In the following paragraphs these relationships have been studied per category of solid flooring.

3.1 Fully slatted floor (category I)

Seufert et al. (1980) found that with a slat width of 150 mm there are less blocked gaps when gap width was increased from 15 to 30 mm. The permeability of the total floor area increased from 8% at 15 mm gap width to 17% at 30 mm gap width. The percentage of blocked gaps decreased from 25% to 1%. They suggested that when gap width is constant at 25 mm, a higher percentage of drainage through smaller slat is not an advantage. At a slat width of 65 mm (permeability is 38%) the percentage of obstructed gaps is 6% and at slat width of 150 mm (permeability is 14%) this is 1%.
Greif (1985) found that a fully slatted concrete floor with gap width of 15 mm has very low permeability. Udesen (1989), as cited by the European Food Safety Authority (EFSA, 2005) compared gap widths of 16, 18 and 20 mm. Udesen (1989) did not recommend gave problems with manure removal, whereas gaps of 20 mm gave the best results. Pedersen Skovgaard (1990), as cited by the European Food Safety Authority (EFSA, 2005) compared concrete floors with gap width of 18 and 20 mm and slat width of 67, 70, 75 and 91 mm. The permeability of the floors were between 16 and 20%. They found no differences on hygiene and pen fouling.
Jensen et al. (1997) suggested that where floors are perforated or slatted, rather than solid, hygiene may be improved by reducing the contact between the pig and the faeces/urine. They give recommendations for slat and gap width for concrete flooring in pigs, based on 15 different sources (Table 1).

Table 1 Recommended slat and gap width for concrete flooring in pigs representing a range from 15 sources (Jensen et al., 1997)

	Piglets	Growing	Finishing/Sows
Slat width (mm)	50 – 120	75 – 150	80 – 200
Gap width (mm)	9.5 – 22	12.5 – 25	17 – 30

3.2 <40% solid floor (category II)

Greif (1985) suggested that partly slatted concrete floors with a gap width of 15 mm have bad permeability. Boykel (2001) has compared metal triangle slats, cast-iron slats and concrete slats. In their study, the metal slats had slat width and gap width of 15 mm, the iron slats had slat width and gap width of 10 mm and slat width of 12 mm at gap width of 10 and 20 mm. The concrete slats had a slat width of 63 mm and a gap width of 22 mm. They conclude that concrete slats had the best permeability for manure.

3.3 Reference (category III)

There are no studies found which deal with this category.

3.4 >40% solid floor (category IV)

Aarnink et al. (1993, 1997, 2001, 2006) investigated pen fouling and ammonia emission at 50%, 60% and 75% solid floor. The smaller the part of solid floor the smaller the pen fouling, although 25% slatted floor (with 12.5% drainage openings of total floor) would be sufficient to prevent pen fouling. A higher proportion of solid floor decreased ammonia emission from the manure storage, but increased ammonia emission from slatted floor. Higher temperatures increased pen fouling on solid floors.
Hoofs (1991) investigated pen fouling with manure and urine on 43% solid floor and metal triangle slats or concrete slats. The metal triangle slats have a slat width of 20 mm and a gap width of 10 mm, resulting in a permeability of 19%. The concrete slats have a slat width of 100 mm and a gap width of 20 mm (permeability of 8.5%). The metal slats lead to less pen fouling than the concrete slats. On a scale of 1-10 the metal slats have a score of 7.5 whereas the concrete slats have a score of 6.5. They found no effect on performance (growth, feed conversion ratio), but cleaning of the pen took 19% less time on the metal slats with higher permeability.

Spoolder et al. (2002) compared three systems with 60% solid floor and a reference system with 40% solid floor. The slatted floor had metal triangle slats and in the pen a ‘dunging gap’ of 9 cm was present, which made the permeability of the floor rather high. The three systems with 60% solid floor were permeable for 17, 18 and 21% of the total area and the reference system for 24%. The amount of pen fouling for the 60% solid floor was 2.3%, 3.9% and 9.4% of the solid floor area, whereas in the reference pen fouling was 0.8% of the solid floor area. 60% solid floor result in more pen fouling than 40% solid floor.

3.5 Conclusion of environmental aspects

To prevent pen fouling through obstructed gaps there have to be sufficient drainage openings. It is insufficient to look only at gap width or percentage of slatted floor, but it is necessary to look at the total permeability. Seufert (1980) suggested that 8% permeability is insufficient to prevent blocked gaps on fully slatted floors whereas 17% permeability is sufficient. Aarnink suggest a minimum of about 12.5% (of total area) permeability in partly solid floors. When a partly slatted concrete floor is used with 40% solid area this means that the permeability of the slatted area has to be 20%. When the slat width is 80 mm, the gap width has to be 22 mm at minimum to comply with this criterion.

4 Influence of floor type on animal health and welfare

Animal health and welfare aspects in relation to floor quality have been investigated mainly through claw lesions. The effects of flooring factors appear contradictory sometimes.

4.1 Leg and Claw effects

Greif (1985) has compared a fully slatted concrete floor (category I with permeability of 13%) with a partly slatted floor (category II) and a solid concrete floor (category IV with 0% permeability). The incidence of claw problems increased when gap width increased. On a fully slatted floor with gap width of 25 mm the incidence of claw problems was 65% whereas the incidence was 21% with gap width of 17-18 mm. On a solid floor the incidence of claw problems was 35%. Claw condition was best on fully slatted floor (category I) compared with (partly) solid floor (category II and IV). When looking at behaviour, Greif found that pigs prefer slat width of 15 cm above 9 cm and gap width of 17 mm above 20 and 23 mm. He recommended a slat width of 10-12 cm and a gap width of 17-18 mm for slaughter pigs. Greif and Hilliger (1985) as cited by Edwards (1997) observed more claw damages, 21% and 65% respectively, when gap size increased from 17 to 25 mm.
Hoofs (1991) compared two different floors with > 40% solid (category IV). 43% of the floors was solid and one slatted floor had metal triangle slats with slat width of 20 mm and gap width of 10 mm, so the permeability was 19%. The other slatted floor had concrete slats with slat width of 100 mm and gap width of 20 mm (permeability of 9%). The metal slats had only some positive effects on the occurrence and seriousness of diarrhoea through better hygiene. There were no differences in relation to leg problems.
Nielsen et al. (2002) investigated lameness on pigs from 98 herds at slaughterhouses in Denmark. Overall 1.8% of the approx. 153,000 finishing pigs observed showed lameness at inspection. They found that the relative risk factor for lameness prevalence was highest (2.26) for pigs housed on fully slatted floors (category I) and lowest (1.75) for pigs housed on solid floor (category IV). The risk factor on partly slatted floors (category II) was 1.92.
Candotti (2004) suggest that on a > 40% solid floor (category IV) there are less clinical symptoms of lameness than on a fully slatted floor (category I, 18% permeability), 15% and 29% respectively. In both cases the slatted area has slats with 20 mm gaps. He found no significant differences in injuries to the front legs.
Rähse and Hoy (2007) observed no effect of proportion of slatted floor and slat width on the claw health of rearing pigs. When gap width increased above 20 mm there was a tendency for claw changes. A 'stallitboden' resulted in the most claw changes (28.5%).

4.2 Diseases

The work of Smith (1992), as cited by Edwards (1997), showed that there was a positive relationship between pigs with bursitis and rearing on hard floors, as well as between the prevalence and severity of bursitis and concrete slats. In an experiment on different floors the incidence of bursitis increased from 57% at the start of rearing to 100% at the end of rearing of pigs kept on a fully slatted concrete floor. For pigs kept on a solid concrete floor the incidence of bursitis increased from 67% at the start to 93% at the end of the rearing period.
Lyons et al. (1995) and Mouttoutou (1999) measured the prevalence of bursitis in rearing pigs. They compared a fully slatted concrete floor (category I) with slat width of 100 mm and gap width of 20 mm with a bare-concrete floor with a slope of 6.25% (category IV). The permeability surface of the slatted floor was 15% and the prevalence of bursitis was 92.8%. The permeability surface of the bare-concrete floor was 0% and the prevalence of bursitis was 80.7%. However, through the slope of the bare-concrete floor, manure end up outside of the pen.
According to Rantzer and Svendsen (2001) there are more weaned piglets with no morbidity at fully slatted floor in a farrowing pen than on partly slatted floor (>40% solid), 94% and 86% respectively. The percentage of piglets recorded with disease problems (mainly diarrhea) is also lower on fully slatted floor (6%) than on partly slatted floor (13%).

4.3 Conclusion on health and welfare aspects

Different floor types do not have the same effect on health aspects. Gaps which are too wide (>20 mm) can lead to claw problems. Fully slatted floors (category I) increase the risk of lameness compared with partly solid floors (category II and IV) and the prevalence of bursitis is higher on fully slatted floors. On the other hand there was a lower incidence of disease associated with fully slatted floors.

5 Influence of floor type on salmonella

Few authors have investigated the prevalence of salmonella in relation to different floor types. Davies et al. (1997) compared the prevalence of salmonella in faecal samples from finishing pigs and in feed samples from 28 swine herds in North Carolina, USA. Prevalence of salmonella in the faeces was lower for pigs raised on slatted floors (category I) compared with all other floor types, 16.5% and 36.7% respectively. In a factor analysis Wolf (2000) did not find floor type as a factor of influence on the prevalence of salmonella in pens with rearing pigs. Nollet et al. (2004) found a prevalence of salmonella of 54% on fully slatted floors (category I), 91% on partly slatted floors (1-50% solid) and 100% when more than 50% of the area has solid floor (category IV). Cook and Miller (2005) reported that solid floor (category IV) increased the risk of salmonella infection and Meyer (2005) reported that partly slatted floor (category II) increased this risk compared with fully slatted floor (category I).

Conclusion on salmonella
Most references conclude that the risk for salmonella is lowest at fully slatted floors (category I), although Wolf (2000) found no influence of floor type. As the references do not describe the gap width of the slatted floors, the permeability of the floors cannot be estimated.

6 Integrated approach

As stated in the introduction, there is insufficient knowledge on how a combination of factors as a minimum of solid floor, a maximum for drainage openings in this solid floor and the gap and slat width of the slatted floor affect animal welfare and what the effects on pen fouling are. The reason is that the majority of studies described in the literature focus on a single aspect. An integrated approach is required to provide a better understanding of floor performance. The present study uses information from a lot of references and adds the factor 'permeability'. We suggest that gap width and percentage of slatted floor is important, but that a minimum percentage of permeability of the total floor area is crucial for good performance of the floor.

6.1 Substance of permeability

One reference which gives good insight in the importance of good permeability is Seufert et al. (1980). Based on the data in this reference, Figure 1 and 2 were made to illustrate the relationship between gap width and slat width. On a fully slatted floor for rearing pigs the percentage of obstructed gaps with manure approached 0% at slat width of 150 mm and gap width of 25 mm. The permeability of the floor area is 14% at that point.

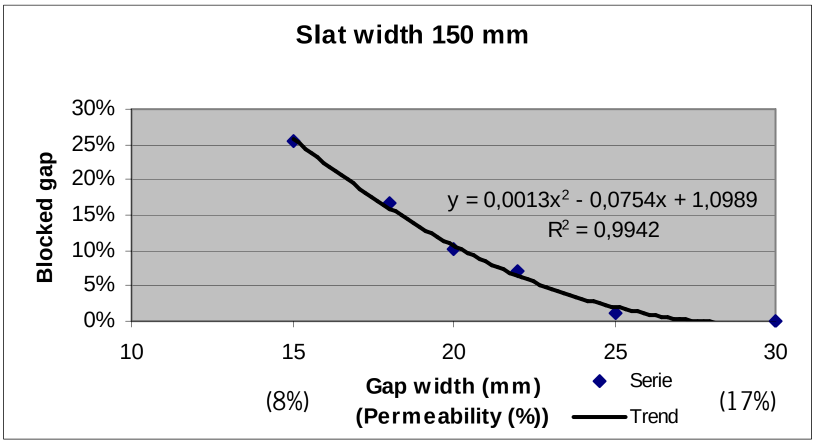

Figure 1 Relationship between gap width, permeability and blocked gap (based on Seufert, 1980)

When gap width is kept constant at 25 mm, increasing permeability through smaller slat width hardly affects the percentage of obstructed gaps. At permeability of 17% there is 1% obstructed gaps whereas at permeability of 38% there is 6% of obstructed gaps (Figure 2).

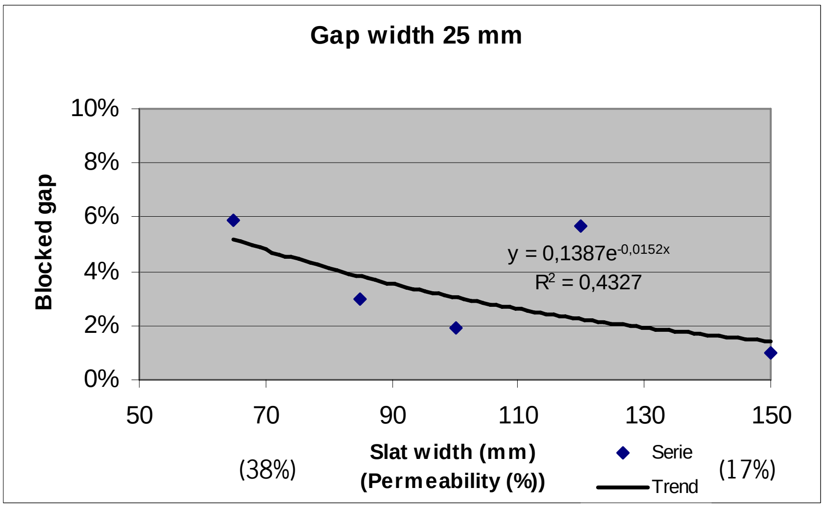

Figure 2 Relationship between slat width, permeability and blocked gap (based on Seufert, 1980)

6.2 Health and welfare

By bringing together different references the effects on animal health and welfare can be visualized. Figure 3a and 3b summarize the differences between the flooring categories in claw lesions. The category with the highest prevalence is set at 100% and the other categories are related to this. Generally the prevalence of claw problems is higher at fully slatted floor (category I) than at >40% solid floor (category IV). However Greif (1980) found a relationship between partly solid floor (category II) and gap width. They found (despite some missing values) that when gap width is 15 mm or 22-23 mm, prevalence of claw problems is higher when part of solid floor has increased. When gap width is 18 mm or 20 mm the results are variable.

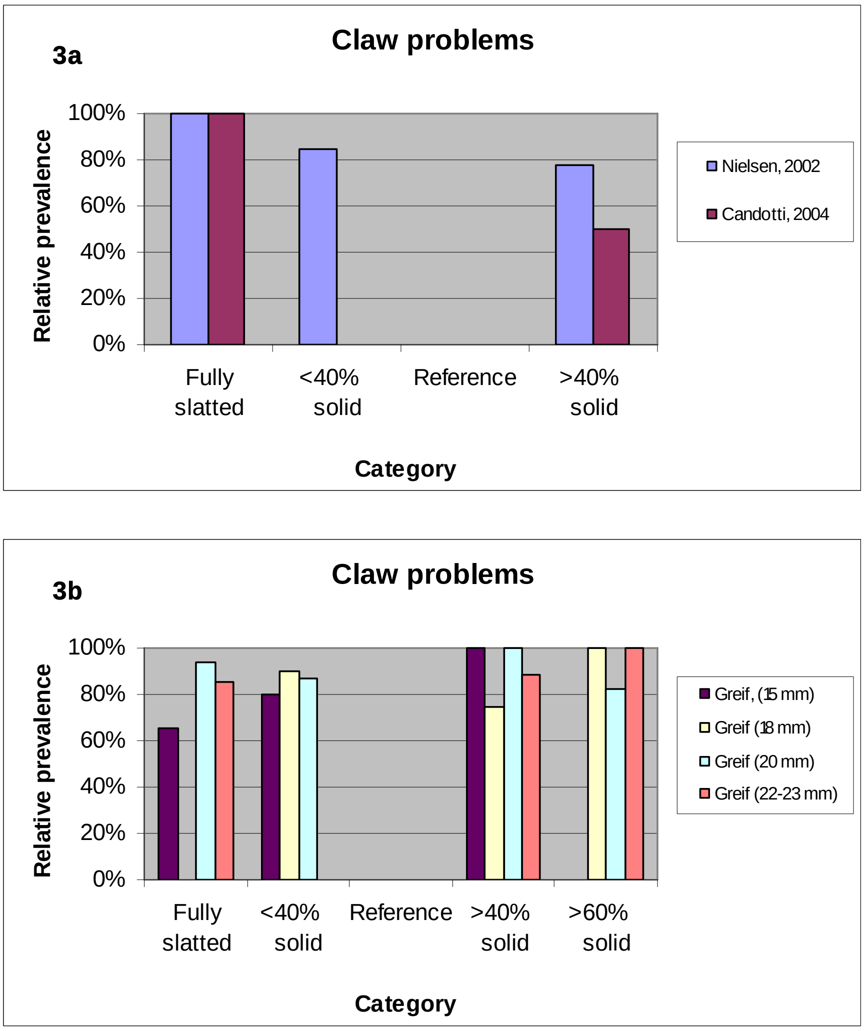

Figure 3 Prevalence of claw problems on different floor categories

In Figure 4 the relative prevalence of salmonella on different categories is visualized. The category with the highest prevalence is set at 100% and the other categories are related to this. Both references suggested that the prevalence of salmonella increased when a partly solid floor is compared with a fully slatted floor.

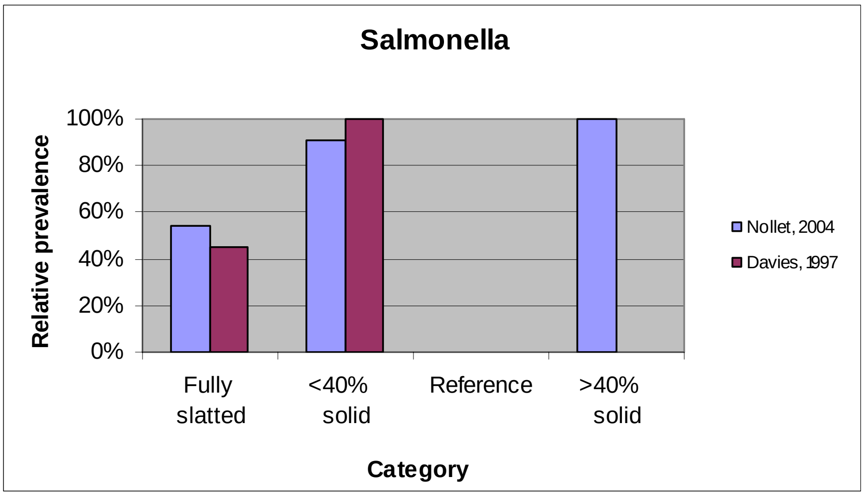

Figure 4 Prevalence of salmonella on different floor categories

In Figure 5 the relative prevalence of bursitis on different categories is visualized. The category with the highest prevalence is set at 100% and the other categories are related to this. The prevalence of bursitis is very high, but on >40% solid floor 10-15% lower than on fully slatted floor, where the prevalence is 100%.

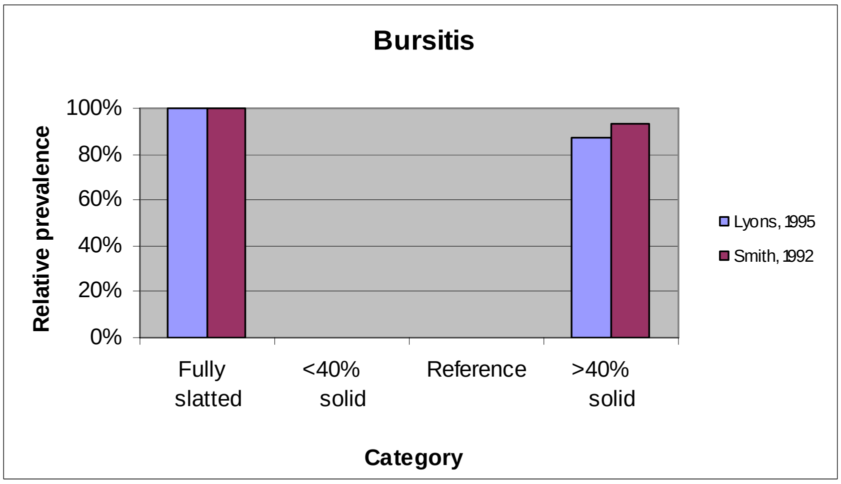

Figure 5 Prevalence of bursitis on different floor categories

In Figure 6 the relative prevalence of illness and bacteria on different categories is visualized. The category with the highest prevalence is set to 100% and the other categories are related to this. The prevalence of illness is with 100% on >40% solid floor more than twice as high as on fully slatted floor. The prevalence of bacteria is very high, but on fully slatted floor 10% lower than on >40% solid floor, where the prevalence is 100%.

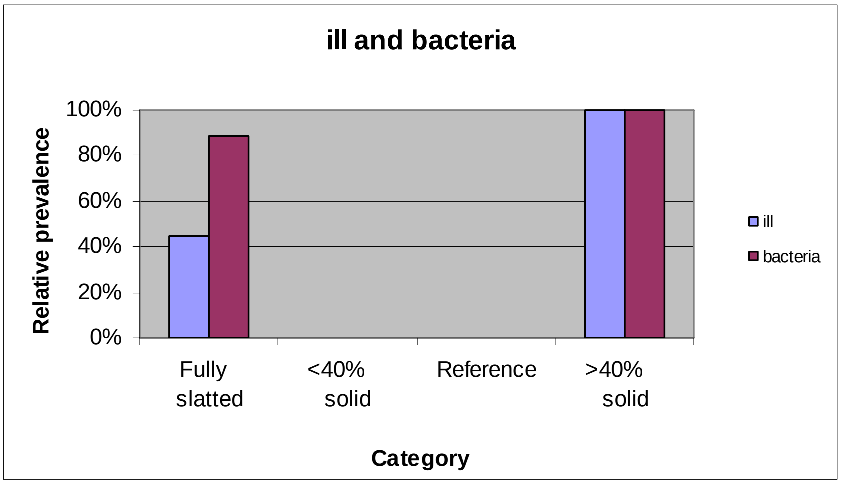

Figure 6 Prevalence of illness and bacteria on different floor categories (Rantzer, 2001)

6.3 Summarized effects

The aim of this review was to model the effects of flowing factors on some aspects of floor quality. During the course of the study it became apparent that it is impossible to do so with the data available in the scientific literature. However, for the majority of aspects it is possible to draw general statements regarding flooring categories. To facilitate this, a visualisation with red and green colours for negative and positive aspects respectively was chosen. Figure 7 represents the relative positive and negative effects of the floor types on the different topics. Compared with >40% solid floor a fully slatted floor is positive for the topics pen fouling, disease incidence, claw problems and salmonella prevalence. On the other hand, fully slatted floor are negative for claw injuries, lameness, claw defects and prevalence of bursitis. The information in the references was not sufficiently quantitative to scale green and red items within a category.

	Reference	**Fully slatted**	**<40% solid floor**	**Reference; 40% solid floor, 18 mm**	**>40% solid floor**
	Author			No information	
Pen fouling	Jensen	green			red
Pen fouling	Rantzer,2001		green		red
Health	Rantzer,2001	green			red
Salmonella	Nollet,2004	green	red		red
Salmonella	Davies,1997	green	red		
Claw problems	Greif, 1985	green	red		red
Claw injuries	Jensen,1997	red			green
Claw defects	Candotti,2004	red			green
Lameness	Nielsen,2004	red			green
Bursitis	Lyons, 1995	red			green
Bursitis	Smith, 1992	red			green

Figure 7 Relative scores of floor types on different topics; green is positive compared with red

7 Discussion

Analyses of a large number of references reveals that almost all studies take a single aspect approach. The findings of those references are difficult to compare. Combinations of aspects and floor types were missing in the literature. There are recommendations for gap width, but those apply to fully slatted floors. Recommendations for gap width when a partly solid floor is available are missing, and there are no scientific recommendations regarding drainage openings in solid floors. Surprisingly enough, we did not find data on the Reference floor in relation to the topics environment, welfare & health and salmonella in the literature.
Good permeability of floors in pig pens is essential in relation to environmental aspects (especially pen fouling), animal health and welfare and to prevent salmonella, but in literature this aspect is underexposed. The permeability consists of a combination of a (partly) slatted floor, slat width and gap width.

The data needed to model flooring factors correctly can be obtained in two ways:

- an experiment in which different floor designs are compared with each other on aspects of animal welfare and the environment. This study will allow a balanced design of data which should yield the most appropriate input for the model. However, it will be rather expensive.
- a survey of existing housing systems. This study requires a wide range of farms to participate, so that the data cover a range of flooring factors and effects on quality aspects.

The second option seems the most feasible one to conduct.

8 Conclusions and recommendations

- Since good permeability is essential, but underexposed, we advise to take this factor more into account.
- Studies in which different permeability's of the floor are compared indirectly, suggest a minimum permeability of 12% is required for good drainage.
- Fully slatted floors generally have a higher percentage of permeability (20%) than (partly) solid floors. Partly solid floors can only achieve the same permeability as fully slatted floors if the gap width in proportion to the slat width is increased.
- The permeability of floors from standard Dutch farms (Category III "Reference") is 9%, which potentially is too low.
- Partly solid floor (category II and IV) are associated with less claw injuries, lameness and bursitis compared with fully slatted floors (category I). However, for part slatted systems pen fouling and associated prevalence of pathogens (e.g. Salmonella) are still problems which need to be addressed firmly before these systems can be considered a success. Good drainage is essential.
- There are no studies to link the total percentage of permeability to floor performance in part slatted systems. However a modeling exercise will clarify the ground rules for design and legislation for floors in the future. The data needed for this model can best be obtained through an international survey of floors in pig pens.

References

Aarnink, A.J.A., Hoeksma P., Ouwerkerk, E.N.J. van, 1993. Factors affecting ammonium concentration in slurry from fattening pigs. In: Proceedings Congress on Nitrogen Flow in Pig Production and Environmental Consequences, Verstegen, M.W.A ., den Hartog, L.A., van Kempen, G.J.M., Metz, Pp. 413 – 420 Pudoc Wageningen, 1993.

Aarnink, A.J.A, D . Swierstra, A.J. van den Berg , L . Speelman, 1997. Effect of Type of Slatted Floor and Degree of Fouling of Solid Floor on Ammonia Emission Rates from Fattening Piggeries. *J . agric . Engng Res .* (1997) 66 , 93 – 102.

Aarnink, A.J.A., J. W. Schrama, R.J.E. Verheijen and J. Stefanowska, 2001. Pen Fouling in Pig Houses Affected by Temperature. Pp. 180-186 in Livestock Environment VI: Proceedings of the 6th International Symposium (21-23 May 2001, Louisville, Kentucky, USA) eds. Richard R. Stowell, Ray Bucklin and Robert W. Bottcher. Pub date May 21, 2001. ASAE Publication Number 701P0201.

Aarnink, A.J.A, J. W. Schrama, M. J. W. Heetkamp, J. Stefanowska, and T. T. T. Huynh, 2006. Temperature and body weight affect fouling of pig pens. Animal Sciences Group of Wageningen University and Research Centre, P.O. Box 65, 8200 AB, Lelystad, the Netherlands. In: J. Anim. Sci. 2006. 84:2224–2231

Candotti, P., S. Rota Nodari, I. Archetti, E. De Angelis, G. Caldara and P. Borghetti (2004). Influence of floor type on the incidence and severity of leg weakness syndrome and of articular osteochondrosis in Italian heavy pig. Proceedings of the International Society for Animal Hygiene, 2004, 53

Davies, P.R., W. E. M. Morrow, F. T. Jones, J. Deen, P. J. Fedorka-Cray and I. T. Harris (1997). Prevalence of salmonella in finishing swine raised in different production systems in North Carolina, USA. In: Epidemiol. Infect. (1997), 119, 237±244.

Edwards, S., J. Robertson, D. Arey and A. Sinclair (1997). Flooring systems for pigs; a review of the scientific and technical literature. The British Pig Association, 1997.

Enting, J., I. Vermeij, A.J.J. Bosma and A. van Buiten, 2006. Level playing field in de varkenshouderij. Implementatie, interptretatie en controle op naleving van EU-richtlijnen voor de varkenshouderij. Animal Sciences Group, Wageningen UR, Lelystad.

European Food Safety Authority-AHAW panel, 2005. The welfare of weaners and rearing pigs: effects of different space allowances and floor types". EFSA-Q-2004-077; Accepted by the AHAW Panel on 15th – 16th March 2005.

Greif, G. (1985). Investigations on slatted floors in pig fattening units. Proceedings, V Internationaler Kongress fur Tierhygiene, Band 1. 1985; 379 – 384.

Hoofs, A. (1991). Metal triangle (slats) in pens for fattening pigs with a concrete closed floor with a slope towards the slats of spherical shape. Proefverslag Proefstation voor de Varkenshouderij. 1991; (PI.73):20 pp.

Jensen, P., E., von Borrel, D.M. Broom, D., Csermely, A.A., Dijkhuizen, S., Hylkema, S.A., Edwards, F., Madec & C. Stamataris (1997). Report of the Scientific Veterinary Committee (Animal Welfare Section). Council Directive EEC. Doc XXIV/B3/ScVC/ 0005/1997.

Lyons, C.A.P., J.M. Bruce, V.R. Fowler, P.R. English, (1995). A comparison of productivity and welfare of growing pigs intensive systems. In: Livestock Production Science 43 (1995) p 265-274.

Mouttotou, N., F.M. Hatchell, L.E Green (1999). Prevalence and risk factors associated with adventitious bursitis in live growing and finishing pigs in south-west England. In: Preventive Veterinary Medicine 39 (1999) 39-52.

Nielsen, E.O., A.G. Hasssing, H. Wachmann, P. Baekbo, H.H. Petersen and J. P. Nielsen, (2002). Associations between housing system, management and lameness in slaughter pigs. In: 17th International Pig Veterinary Society Congress. Ames, Iowa, USA, 2-5 June 2002.

Nollet, N, D. Maes, L. De Zutter, L. Duchateau, K. Houf, K. Huysmans, H. Imberechts, R. Geers, A. de Kruif, J. Van Hoof (2004). Risk factors for the herd-level bacteriologic prevalence of Salmonella in Belgian slaughter pigs. In: Preventive Veterinary Medicine 65 (2004) 63–75.

Rähse, E. and St. Hoy (2007). Untersuchungen zu Häufigkeit und Schweregrad unterschiedlicher Klauenveränderungen bei Mastschweinen unter Berücksichtigen der Haltungsbedingungen. In: Praktischer Tierarzt 88: 1, 40-47 (2007).

Rantzer, D. and J. Svendsen, (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. A, Animal Sci. 2001: 51, 175 –183.

Seufert, H., Jungbluth, T., Greif, G. (1980). Suitability of perforated floors for pig husbandry. Landtechnik. 1980; 35(8/9): 404 – 408.

Spoolder, H.A.M. (2002) Pens for finishing pigs with 60% solid floor area. PraktijkRapport 1, Praktijkonderzoek Veehouderij, Wageningen UR, Lelystad.

Spoolder, H.A.M., Hoofs, A.I.J., Hulsegge, B., Hopster, H., (2002). Applied research to support welfare policy making: a study to investigate solid floors for pigs. In: Proceedings of the annual meeting of the International Society for Applied Ethology, Egmond aan Zee, The Netherlands, August 2002.

Tierschutz-Nutztierhaltungsverordnung (2006). Verordnung zum Schutz landwirtschaftlicher Nutztiere und anderer zur Erzeugung tierischer Produkte gehaltener Tiere bei ihrer Haltung (Tierschutz-Nutztierhaltungsverordnung – TierSchNutztV). In der Fassung der Bekanntmachung vom 22. August 2006, BGBl. I S. 2043, geändert am 30. November 2006, BGBl. I S. 2759

Wolf, P.J., van der (2000). Salmonella in the pork production chain: feasibility of salmonella-free pig production. Thesis University of Utrecht, ADDIX, Wijk bij Duurstede, the Netherlands.

Appendix A

Category	
1	**Fully slatted floor**
2	**Solid floor (till 40%) with good permeability**
	Reference with 40% concrete solid floor, 60% slatted floor with gap width 18 mm
3	**Solid floor (40-60%) with limited permeability**

green = positive effect compared to red
red = negative effect compared to green

Reference			**1 Fully slatted floor**		**2 Solid floor (<40%)**		**3 Solid floor >40%**	
Author		**weight**	**% drainage**		% drainage		% drainage	
Environment								
Aarnink, 1993	rearing pigs	30-95 kg					12,5%	50 and 75% solid floor
Dung- and laying behavior	pen fouling						25%	25% slatted floor is (within comfort zone) sufficient to prefer pen fouling
in relation to								pigs prefer laying on a solid floor more than on slatted floor
pen design and ammonia								
Aarnink, 1997	weaned piglets	10-25 kg					12,5%	50% and 75% solid floor (rest metal slats); slat and gap width 10 mm
Thesis	ammonia						25%	slope solid concrete floor 2% with 75% solid, 4% with 50% solid, dunging gap 6 cm.
								75% solid floor result in 20% decrease NH_3 emission compared with 50% solid floor
	rearing pigs	28-106 kg					6%	50% and 75% solid floor (rest metal slats); slat 70 mm, gap 18 mm
	ammonia						10%	slope solid concrete floor 2% with 75% solid, 4% with 50% solid, dunging gap 8 cm.
								75% solid floor result in 20% decrease NH_3 emission compared with 50% solid floor; n.s.!
								Lower part slatted floor: less emission from the pit, but more from slats!
Aarnink,1997	rearing pigs	26-112 kg						5x category 3: 75% solid floor, 25% slatted floor with 15-50% gap **significant**
Ammonia emission								gap width 10 mm (metal slats) till 18-20 mm (concrete slat)
	ammonia emission							metal slat i.c.with solid floor result in 27% decrease NH_3 emission compared with
	pen fouling							concrete slat i.c. with solid floor. Also pen fouling has decreased.

		Slatted floor		Solid floor		
		Excretion pigs (%)		wetted area	Frequency of excretion	
		Urinations	Defecation	solid floor (m2/pig)	Urinations	Defecation
3,8%	S1	69,4 [abc]	85,6 [a]	0,07 [ab]	24,2 [ab]	10,7 [ab]
4,5%	S2	72,9 [bc]	86,7 [a]	0,10 [ab]	19,4 [b]	7,9 [bc]
8%	S3	62,8 [a]	81,7 [a]	0,11 [a]	28,9 [a]	14,4 [a]
12,5%	S4	65,9 [ab]	85,2 [a]	0,09 [ab]	25,2 [ab]	9,9 [ab]
12,5%	S5	76,2 [c]	95,1 [b]	0,04 [b]	19,1 [b]	3,5 [c]

Aarnink, 2001	rearing pigs	25-105 kg					20%	60% solid concrete, 40% metal triangle slat
	pen fouling							aboven certain temperature excretion on solid floor increase
								in summer it is difficult to prevent pen fouling on solid floor
Aarnink, 2006	excretion i.r.t. temp	25-105 kg					20%	60% solid concrete floor, slope 2.4%. 40% metal triangle slat
								with 12 mm gap and 12 mm slat
								At higher temperature excretion on solid floor increase
								Above 23.5 °C this increase from almost 0% to 80% at 29 °C
Brok en Voermans, 1995	rearing pigs	23-112 kg			40%	0,70 m^2/pig, 22% and 38% solid floor, rest	25%	0,70 m^2/pig, 53% solid, rest
					33%	metal triangle slats, dunging gap 10 cm		metal triangle slat, dunging gap 10 cm
	fouling					max. 0,3 m^2 solid floor per pig (40%) and a		
	no sign difference					dunging gap: no problems with pen fouling.		
						Condition is a good permeable slatted floor		
						eventually i.c. with dunging gap from max 10 cm.		
						Openings till max 5% of area deliver no		
						better pen hygiene		
Greif, 1985	fouling			15 mm gap width: bad permeability		15 mm gap widht: worse permeability		
						with partly slatted floor		
Hoofs, 1991	rearing pigs	23-103 kg					19%	43% solid concrete floor, rest metal triangle slat; slat 20 mm, gap 10 mm
	fouling						8,5%	43% solid concrete floor, rest concrete slat; slat 100 mm, gap 20 mm
								metal triangle slat result in less pen fouling with manure and urine
								On a scale of 1-10 a metal slat scores more than 1 point better:
								concrete slat 6,5 and metal slat 7,5. No effects on technical performance
								Cleaning the pens with metal slat took 19% less time
Rantzer, 2001	piglets	1-8 kg				farrowing pen: 2,5 m^2 plastic slat with urine drain,		solid floor with narrow strip plastic slat (20 cm)
						4,5 m^2 concrete floor		
	pen fouling degree					more clean than at solid floor and less bacterien		
	Lying area					0,17		0,27 n.s.
	Activity area					0,15		0,40
	Dung area					1,00		1,41
	Trough area					0,58		1,08
	Bacterien					7,46		8,58

Reference			1 Fully slatted floor	2 Solid floor (<40%)	3 Solid floor >40%
Author		**weight**	**% drainage**	% drainage	% drainage
Rantzer, 2001	weaned piglets pen fouling score			40% plastic slat, little straw more clean than at solid floor and less bacterien placed non-placed	6% plastic slat, little straw placed non-placed
	Lying area			0,06 0,02 n.s.	0,12 0,06
	Activity area			0,05 0,27 p<0,001	0,50 0,59
	Dung area			0,97 1,39 p<0,002	1,98 1,83
Seufert, 1980	rearing pigs	20->110 kg	8% slat 150 mm gap width:		
	pen hygiene		10% 15 mm 18 mm 20 mm 22 mm	25 mm 30 mm	
	drainage		11% 8,25% 10% 11% 12,2%	13,9% 16,7%	
	% obstructed gap		12% 25,4 16,8 10,2 7,2	1,0 0%	
			14% gap width 25 mm slat width:		
			17% 65 mm 85 mm 100 mm 120 mm	150 mm	
	drainage		38% 38% 26% 22% 18%	14%	
	% obstructed gap		26% 5,9 3,0 1,9 5,7	1,0	
			22% smaller gap width (< 25 mm) increased blocked gaps. 18%		
Siebert, 2003	ammonia		no difference in emission between slatted floor and curved laying area for pigs		
Spoolder, 2002 *(praktijkrapport)*	rearing pig	25-115 kg			comparison 3 systems 60% solid floor with reference 40% solid, all with 1.0 m^2 per pig throug metal triangle slat and dunging gap a high proportion drainage openings!
	pen fouling ammonia				pen fouling: % solid floor / NH_3 (kg) / time for cleaning 18% A 3,9%[a] 1,7 279[a] 17% B 2,3%[b] 1,5 181[b] 21% C 9,4%[c] 2,0 179[b] 24% reference 0,8%[d] 1,5 181[b] cooling of floor in C had no effect on fouling the solid floor Conclusion: 60% solid floor lead to more penfouling than 40% solid floor. (measured by optimal conditions! In situation of renovation probably greater problems). Against disadvantages the advantage for welfare from a greater solid area is probably relative small. In pen C high score throug 1 extreme foul pen! This was the only pen with feed trough on solid floor and 24 in stead of 12 pigs per pen
Svennerstedt, 1999	rearing pigs		38% plastic slats (laboratory) position of drainage slit and % opening area from 'cover' 43% middle, 0,9% middle, 1,8% side, 0,9% side, 1,8% opening		
	total drainage		38% 37,60% 43,4% 37,8% 46,4%		
	urine drainage resp		46% 63,40% 75,2% 58,0% 67,0%		
Vermeer et al., 1995	weaners fouling			30% 0,36 m^2/pig, 33-40% solid, rest metal triangle slat; dunging gap 5 cm minor	
EFSA, 2005	**weaners** **adviced gap width**			1/3 solid concrete floor:	
Jensen & Nielsen, 2004	concrete slat			15% gap width 15-16 mm at slat width 40-60 mm	
Holmgren, 2001	plastic slat metal slat concrete slat			12-15 mm; hygiene score 0.8 33% 10-11 mm; hygiene score 1.1 10-20 mm; hygiene score 1.6	
Jensen & Hansen, 2003	concrete slat				6,5% at 2/3 solid concrete floor: 20-23 mm gap width with slat width 70-80 mm
Jensen, 2003	metal slat				17% at 2/3 solid floor (1/3 metal slat) a gap of 10-15 mm icm slat 10-15 mm has been recommended)
	rearing pigs				
Udesen, 1989	concrete slat		vgl 16-18-20 mm gap. 16 mm is dissuaded due to obstructed gaps best result for manure removal by 20 mm with 18 mm problems with dung removal when using alternative feed ingredients (tard, peas)		
Bookma, 1990	concrete slat		20 mm gap is sufficient for a clean floor concrete require a bigger gap width through rough surface		

Reference			1 Fully slatted floor		2 Solid floor (<40%)	3 Solid floor >40%	
Author		**weight**	**% drainage**		% drainage	% drainage	
Brogaard Pedersen, 2003	concrete slat				concrete slat:when straw is used, 23 mm gap advised		
Pedersen Skovgaard, 1990	concrete slat		19%	vgl 18, 20, 20 en 20 mm gap with			
			20%	67, 70, 75 en 91 mm slat:			
			19%	no difference in hygiene and pen fouling			
			16%				
Boykel, 2001	metal slat				comparison metal triangle (15 mm slat/gap), cast iron (10 mm gap/slat)(10 en 20 mm gap, 12 mm slat) concrete slat (22 mm gap, 63 mm slat) concrete had here the best permeability for manure!		
Jensen, 1997	pen fouling			to prevent pen fouling, there have to be sufficient openings			
	claw problems						the risk of claw injuries is smaller on solid floor than on floors with slots and gaps
Animal health, welfare							
Candotti, 2004	heavy rearing pigs	90-170? kg	18,0%	fully slatted concrete floor, slat 80 mm, gap 20 mm			solid concrete floor with 1 m slat (gap 20 mm)
	healthy			71% n.s.			85% n.s.
	clinical symptoms lameness			29%[b]			15%[a] significant difference (p<0,02)
	front leg joints			OC lesion clinical 10%, subclinical 40% n.s.			OC lesion clinical 6%, subclinical 27% no sign. differences!
				OC = Articular Osteochondrosis			
Nielsen et al, 2002	rearing pigs	100 kg					
	lameness: 1.8%			risk factor lameness is 2.26	risk factor lameness is 1.92		risk factor lameness is 1.75
Greif, 1985				concrete slat, gap width 16-25 mm			
	claw problems			21% at gap of 17-18 mm, 65% at 25 mm		0%	35% when solid floor
			13%	prevalence claw problems increase at decreasing	claw condition the best on fully slatted floor compared with partly slatted or solid floor		
				part slatted floor	at gap width 18 and 20 mm percentage laying area has no influence on claw situation		
	behavior			pigs prefer slat width of 15 cm above 9 cm and			
			12%	gap width of 17 mm above 20 or 23 mm			
			13%	Recommended: gap 17-18 mm, slat 10-12 cm			
Guy, 2002	rearing pigs	30-80 kg	*18%*	fully slatted concrete floor, gap 25 mm (0,55 m^2 per pig)			
	bursitis		21%	inititial - final score 3.5 - 4.4			
	injury			initial - final score 18.9 - 9.2			
	stomach			lesion index 3,5			
	mortality			5.2%			
Hoofs, 1991	rearing pigs	23-103 kg				19%	43% solid concrete floor, rest metal triangle slat; slat 20 mm, gap 10 mm
	fouling					8,5%	43% solid concrete floor, rest concrete slat; slat 100 mm, gap 20 mm
							Better hygiene of metal slat has related to health problems only
							some positive influence on prevalence and gravity of diarrhee
							No difference in relation with leg problems.
Rantzer, 2001	**weaners**			placed / non-placed			placed / non-placed
	Bacterien			8,81[b] / 8,44[a]			9,69[c] / 9,75[d] floor type significant
	% animals not sick			94,7% / 92,9%			91,1% / 81,4% floor type significant
	% dieren 1x ziek			5,0% / 6,8%			8,2% / 18,2% floor type significant
	w.v. diarrhee			4,4% / 5,6%			7,5% / 16,2%
	joint inflammation			0,4% / 0,6%			0,2% / 0,9%
	growth (g/day)			n.s.			
Lyons, 1995	rearing pigs	27-90 kg	15%	concrete slat, 100 mm slat, 20 mm gap		0%	concrete floor with slope of 6.25%, manure comes outside the pen
	bursitis			score 1,52[a], prevalence 92,8%[a]			score 1.06[b], prev 80,7%[b]
Mouttoutou, 1999	rearing pigs		15%	concrete slat, 100 mm slat, 20 mm gap			beton
	bursitis; prevalence			92,8%			80,7%
	extent			1,52%			1,06%
Mouttoutou, Hatchell 1999	bursitis	30-90 kg		74,5%	part concrete and concrete slats: 75,0% part concrete and expanded metal: 90,9%		total solid concrete floor: 40.9% (83% has litter!)
Rähse en Hoy, 2007	rearing pigs						
	claw changes	slaughter		Part slatted floor and slat width has no influence on claw health!			Stallitboden' leads to the most claw changes (to 28.5%)
				With gap width >20 mm tendency for more claw changes			

Reference			1 Fully slatted floor	2 Solid floor (<40%)	3 Solid floor >40%
Author		**weight**	**% drainage**	% drainage	% drainage
Edwards, 1997 Review					
MAFF, 1981	injuries		frequency with slatted floor almoas 2x as much as with solid floor		
Fritschen, 1976			fully slatted floor has higher risk than partly slatted floor		
			for injuries of outside claw, but not of inside claw		
Grief and Hilliger, 1985	injuries		Gap width from 17 mm and 25 mm gave resp. 21% anf 65% claw damages		
Smith, 1992	bursitis				
	incidence		start of period 57%, end of period 100%		start of period 67%; end of period 93%
	score		start of period 0,54, end of period 1,75		start of period 0.83; end of period 1.43
Salmonella					
Beloeil, 2004	sows and fattening pigs		As measure against Salmonella frequently dung removal has been called.		
Nollet, 2004	rearing pigs	slaughter	100% slats	1-50% solid floor	>50% solid floor
	prevalence		54% (95% btbh int: 36 - 70%) [a]	91% (95% btbh int: 61 - 99%) [b]	100% (95% btbh int: 88-100%) [c]
Wolf, van der, 2000	rearing pigs	rearing-slaughter	Flooring type was not a factor of influence on the prevalence of salmonella		
Zheng, 2006	rearing pigs	slaughter	When transmission of S. in the pen is present, slatted floor has been mentioned as variable in a 'correspondence analysis' which contribute to this variability		
	0		for dimension 1: indoor herds (0.18), high stocking density (0.17) and slatted floor (0.12)		
Cook en Miller, 2005					solid floor increase the risk on Salmonella infection
Meyer, 2005				partly slatted floor increase the risk on Salmonella compared with fully slatted floor	
Davies, 1997	rearing pigs	rearing-slaughter	study on 28 farms in the USA, divided in fully slatted floor and solid floor with drainage openings		
	prevalence		16,5%	36,7%	
Odor					
Mol en Ogink, 2002	Stalsystemen ontworpen voor de terugdringing van ammoniak, vertonen geen eenduidig beeld t.a.v. de reductie van de geuremissie. Naast het stalsysteem spelen andere factoren een belangrijke rol. Klimaats- en gewichtsgerelateerde factoren die zij gekoppeld aan de stalventilatie, oefenen een duidelijk significant effect op de geuremissie. Ook tal van andere factoren, zoals bijv. voertype, bedrijfshygiene, de specifieke luchtstromingspatronen in de stal, en de dieractiviteit hebben een grote invloed op de geuremissie.				
Average drainage			**20,8%**	**30,2%**	**13,7%**

Drainage% betonroosters is berekend door spleetbreedte:balkbreedte * 0,9