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The effect of space allowance for finishing pigs on productivity and pen hygiene


a Danish Agriculture and Food Council, Pig Research Centre, Axelborg, Axeltorv
3, DK-1609 Kbh. V. Denmark

b Animal and Veterinary Sciences, SAC, West Mains Road, Edinburgh, EH9 3JG,
U.K.

* Corresponding Author. Tel: +45 (0)3339 4426; fax: +45 (0)3391 0500. E-mail address: tje@lf.dk

Abstract

Space allowance for housed farm animals is a contentious animal welfare issue for producers, policy makers and the public. A recent European Food Standards Agency report (EFSA 2005) proposed an increase in space allowance for growing pigs. Reduced stocking rates per building cost producers in terms of reduced throughput, but might be in part compensated by improved productivity or pen hygiene. To investigate this we compared three different space allowances, (0.67 m²/ pig, 0.73 m²/ pig and 0.79 m²/ pig) for groups of 14 finishing pigs (32.01 kg to 91.25 kg) over 65 +/- 10 days on two commercial pig farms (91 -92 pens of each size, 7672 pigs). The lowest space allowance (0.67 m²/ pig) was close to the current EU recommended minimum space allowances of 0.65 m²/ pig. Wet feed was provided in long troughs with 34 cm per pig of feeder space and all pens were part-slatted (1/3 solid floor).

There were non-significant tendencies for improved daily gain (p = 0.07) and a higher gross margin per pig (p = 0.06) at the two larger space allowances. There were no significant differences in feed efficiency, lean meat, or mortality (which was very low). There was also no effect of increasing space allowance on pen hygiene in either the solid-floored lying area or the activity area in the middle of the pens. The percentage of pens with faecal soiling all over the lying area or the number of pens in need of daily cleaning, was not affected by increasing the space allowance from 0.67 m²/pig to either 0.73 m²/pig, or 0.79 m²/pig. Pen hygiene deteriorated as pigs aged, since soiling on the solid floor and wallowing behaviour was most prevalent in the late growing period.

In conclusion, there was no evidence that productivity or pen hygiene were improved by increasing the space allowance of finishing pigs from 0.67m²/pig to 0.79m²/pig in well-managed commercial pig systems, suggesting that such an increase would be costly to producers.

Keywords: swine; stocking density; housing design; growth; pen fouling

1. Introduction

Space allowance (area per animal) is of considerable interest to animal producers, policy makers and animal welfare groups, and is an important aspect
of public concerns over intensive farming across species (SVC, 1996; SVC, 1997; Estevez, 2007). Determination of space requirements often takes an allometric approach (Petherick, 1983; Hurnik and Lewis, 1991; Gonyou et al., 2006), where the area required is expressed in relation to body weight \( (A = k \times BW^{2/3}) \).

The second part of this equation \( (BW^{2/3}) \) describes a property of any object that retains the same overall shape as it increases in size. Weight increases in proportion to the 3 dimensions of volume (width, length and height), but the floor area needed increases in proportion to 2 dimensions (width and length). The constant \((k)\) that this is multiplied by is then a useful descriptor of space allowance (using the S.I. units of \( m^2 \) and kg).

The current EU minimum space allowance for 85-110 kg finisher pigs of 0.65 \( m^2/pig \) came into force for new builds from January 1994 and all farms from January 1998 (The Council of The European Union, 1991). In terms of \( k \), this recommendation ranges from 0.0336 at 85kg to 0.0283 at 110kg. In 2005, the Scientific Panel on Animal Health and Welfare of the European Food Safety Authority reviewed the scientific evidence on pig space allowance in terms of welfare, health and ammonia production (EFSA AHAW panel, 2005). They recommended that pigs under 110kg should be housed at no less than \( k = 0.036 \) (at a temperature under 25°C). They argued that daily gain would be optimized, and that pigs would have sufficient space to lie in something between sternal recumbency and full (side) recumbency. A recent meta-analysis showed that at least \( k = 0.039 \) was required to provide sufficient space for pigs to lie down (Averos et al., 2010). Despite the recommendation of the EFSA report, space allowance remained unchanged in the most recent version of the standards (The Council of The European Union, 2008).

In addition to this policy background, various industry trends make a re-evaluation of stocking density for finishers timely. Slaughter weights for pigs have been increasing and this trend is continuing (Kim et al., 2005). New pig diseases have become endemic in many countries in recent years (e.g. PRRS, Done et al., 1996; PMWS, Chae, 2004; Baekbo et al., 2012), which may be exacerbated by social stress (Sutherland et al., 2007; Alarcon et al., 2011) resulting in recommendations to producers to reduce stocking density below the prescribed statutory requirements (ThePigSite, 2003; Hassing and Bækbo, 2004). Also, space requirements might vary depending on the floor type, for example comparing fully slatted and part-slatted systems (EFSA AHAW panel, 2005; but see Gonyou et al., 2006), and on the provision of manipulable substrates (The Council of The European Union, 2001).

Two aspects of stocking density that are of considerable interest to producers are productivity and pen hygiene. Small space allowance can adversely affect the growth of individual pigs. A recent meta-analysis of published papers on this topic showed that growth improves linearly with space allowance until some threshold when growth plateaus (Gonyou et al., 2006). This threshold was estimated to occur at around \( k = 0.0317 \sim 0.0348 \). Pigs naturally seek to avoid defecating in their lying area (Whatson, 1985) and hygiene could be adversely affected if there is insufficient space for pigs to separate their dunging and lying areas. Hygiene generally deteriorates as pigs get larger in the same pen (Hacker et al., 1994; Rossi et al., 2008), which could be due to an increase in the effective stocking density (\( k \) reduces as pigs get heavier in the same space), or may be an age-related effect.
In the present study, we investigated whether the increased financial cost of larger pens (or of fewer pigs in the same building) might in part be offset if either i) an increased space allowance resulted in more efficient growth of pigs, or ii) in reduced labour inputs in terms of less manual cleaning of the solid area of part-slatted pens.

2. Materials and methods

2.1. Animals and Housing

The subjects of this study were 7672 commercial line (LYD, Large white/Yorkshire x Duroc) finisher pigs, approximately 11 weeks old at the start of the study. Starting weights are given in table 2. Prior to the start of the experiment the pigs had been housed in a weaner facility, in two-climate pens (i.e. having a warmer covered area providing 0.08-0.1m² per pig under cover) with 30-40 pigs per pen. Pigs were mixed into single sex groups of uniform weight at weaning and when they were moved to the finisher facility.

The study was conducted on two commercial pig farms in Denmark over an 18 month period. Farm A had spaces for 2016 finishers, consisting of 24 pens (4.78m × 2.28m) each housing 14 pigs (useable floor space allowance, allowing for trough space = 0.72m²/pig) in each of 6 rooms. Farm B had spaces for 1568 finishers, consisting of 28 pens (4.80m × 2.34m) for 14 pigs (useable floor space allowance 0.73m²/pig) in each of 4 rooms. Both farms had part-slatted floors in all pens (slats were 8 cm wide with a gap of 2 cm between them), with 1/3 solid floors. Fully-slatted systems are not allowed in Denmark from 2000 (new installation) or 2015 (any farm) (Justitsministeriet Danmark, 2000). Small amounts of straw were provided daily on the solid areas in Farm A, and both farms had permanent access to wooden sticks as a manipulable substrate (as required by The Council of The European Union, 2001). In Farm A the wooden sticks were placed in two holders on the pen partition, and in Farm B they were placed on the floor and fixed by chains to the pen partition. The sticks were soon destroyed by the pigs and so were regularly replaced. In both farms, liquid feeding in a long trough 4.8m long provided 34cm of feeder space per pig. In both Farm A and B there was a drinking bowl (Egebjerg) placed on the pen partition opposite the trough. Climate control was achieved by means of an electronically-controlled mechanical pressurised air ventilation system with diffused air intake. Control system temperature curves were set to a stocking density of 0.73 m²/pig (Table 1), but actual temperatures were not recorded.

The allocation of space allowance treatments within each room (see below) ensured that there were few differences between rooms in average stocking density. Both farms had water sprinklers for hot weather (activated when the outdoor temperature was above 12 °C), located over the slatted part of the pen. Sprinklers came on for 45 seconds every 30mins between 0800hrs and 2000hrs. Farm B had air heaters for cold weather.

PRRS were present on both farms and probably also PMWS at Farm B. There were no outbreaks of clinical disease, but the causative agent which is thought to be porcine circovirus type 2 (PCV2) was present (Danish Veterinary Laboratory, Copenhagen).
2.2. Space allowance treatments

Each farm had pens arranged in mirror-image pairs, such that the automatic feeding system pipes served a trough each side of a central pen divider, thus the trough was on the left in one pen and on the right in the adjacent pen. The existing pens provided 0.73 m²/pig on Farm A and between 0.72 and 0.75 m²/pig on Farm B. To create pens of two additional sizes, sets of 12 pens (6 pairs of pens sharing the same trough) within a room on each farm were modified, either by moving the dividing pen wall opposite the trough, or by inserting a double pen wall if only one of two adjacent pens needed to be smaller (Figure 1). This resulted in 6 enlarged pens (3 pairs) per room (Farm A 0.79 m²/pig; Farm B 0.78-0.80 m²/pig), and 6 smaller pens (3 pairs) per room (Farm A 0.67 m²/pig, Farm B 0.66-0.68 m²/pig). A further six (3 pairs) of unmodified pens in each room were used for the control treatment.

For simplicity, the smaller, intermediate (unmodified) and enlarged pens are respectively referred to as 0.67m²/pig, 0.73 m²/pig and 0.79m²/pig from now on.

On Farm A, 6 rooms were modified as described, providing 54 pairs of pens for the experiment (18 of each space allowance). On Farm B there were 3 rooms modified, resulting in 27 pairs of pens (9 of each space allowance). Each pen was used several times. In total, the study involved 91 pairs of pens (56 Farm A, 35 Farm B) of each of the 0.67m²/pig and 0.73 m²/pig pens and 92 pairs of 0.79 m²/pig pens (56 Farm A, 36 Farm B).

2.3. Production data

Pigs were allocated to treatments to balance for weight on a pen average basis. The 28 pigs in each double pen remained in the same group throughout, except when pigs had to be removed due to health problems or mortality. Records of these were kept. Sick pigs were separately housed for veterinary attention and were not returned to their pens during the experiment.

At the end of the finishing period, pigs were weighed again before being sent for slaughter. Using the number of days between first and last weighing, average daily gain was calculated. All pigs were weighed just before the first pigs from the batch/room were sent for slaughter. Pigs were transported in a lorry to one of Danish Crown’s slaughterhouses either in Ringsted (Farm A) or in Herning (Farm B). The transport distance/time was 82 km taking approximately 1 hr (Farm A) or 92 km taking approx 1.5 hrs (Farm B). At slaughter, lean meat percentage was measured by the classification centre method (http://www.klassificeringskontrollen.dk/). In summary, the carcass is fixed and at seven standardised locations in the ham, back and neck the meat/fat thickness is measured by light reflection. This was traceable back to treatment because pigs were marked for slaughter according to space allowance. Pigs could not be traced to specific pens.

Total feed consumption was recorded on the double pen level between the first and last weighing, enabling feed conversion efficiency to be calculated using standardised feed units (Feed Units growing pig) FUgp/ kg of weight gain. FUgp
is a Danish way of expressing the energy content of the feed. 1 FUgp = 7.38MJ physiological energy or 12.52 MJ metabolic energy.

**2.4. Assessment of pen hygiene**

Assessments of pen hygiene were made every 14 days, resulting in 1788 recordings of pen hygiene in total across the two farms. For the purposes of hygiene recordings, each pen was visually divided into 9 equal-sized zones using pen landmarks. The pen was first divided into three strips (the solid-floored lying area at the back of each pen, the middle of the pen, and the dunging area closest to the corridor at the front). These were each divided into three (the side closest to the feeding trough, middle area, side furthest from the feeding trough). The 9 zones were each observed and given a % value, estimating the area of faecal contamination within that part of the pen. Clean dry zones were given a value of 0%, zones with an estimated 1-24% of their surface area covered in faecal contamination, or which were wet were given 12.5%, zones with 25-49% faecal contamination scored 37.5%. areas with 50-74% contamination were given 62.5%, while areas with 75-100% contamination were given 100%.

Every 14 days, at the same time as the pen was being scored, the cleanliness of the pigs themselves was scored on a 4 point scale on a group/pen basis as follows: Pigs clean and dry (0% of body surface is dirty) = 1, Pigs partially dirty (1-50% of the body surface is dirty) = 2, Pigs are dirty = 3 (50-99% of the body surface is dirty), Pigs are completely covered in faeces (100% of body surface dirty) = 4. To further assess pen function, the cleanliness of the slatted floor was recorded on a scale from 1 to 4: Slatted floor clean = 1, low level of accumulated faeces = 2, faeces accumulated on the floor at the side of the pen = 3, large piles of faeces on the slatted floor = 4.

Although the whole pen was assessed for hygiene, the three zones of the solid-floored lying area were the primary measure of pen hygiene. Two further measures of pen hygiene were derived from these: 1) The number of occasions that a pen required manual cleaning, which occurred when at least 2 of the 3 zones in the solid-floored lying area had faecal contamination covering at least half of the area. 2) The number of occasions when a lying area received the worst possible hygiene rating was noted (i.e. 75-100% contamination of all three zones in the lying area). Each of these derived measures were expressed as a percentage of total observations.

**2.5. Economic Indicators**

The gross margin per pig was calculated on the basis of daily gain, feed conversion and meat percentage. On the basis of these actual values an indexed value was calculated. The gross margin was based on average prices of pig meat and feed over a five year period (September 2005 – September 2010). Gross margin per pig is then calculated as = (sales price - purchase price) ÷ ((FUgp × price (DKK) per FUgp) - diverse expenses).

**2.6. Statistical methods**
Pens with pigs which died or had to be removed due to illness were excluded from the statistical analysis of production or pen hygiene, resulting in a sample size of 61 pairs of 0.67m²/pig pens (1708 pigs), 65 pairs of 0.73m²/pig (1820 pigs) and 67 pairs of 0.79m²/pig pens (1876 pigs; 5404 pigs in total). This was to avoid the problem that removing pigs results in an increase in the space allowance per pig for the remainder. Power calculations before the experiment suggested that at least 56 repetitions would be needed to detect a difference of 10% per annum in the index of production with a power of 80. Thus even this reduced sample size met this requirement.

Production data were analysed at the level of pairs of adjacent pens (28 pigs) that share a feed trough. For analysis of start and end weight, daily gain, feed conversion, carcass lean meat and gross margin per pig, ANOVA models were fitted to determine treatment differences using the procedure MIXED in SAS (F ratios were generated as the test statistic). Pig weight at the start of the trial was fitted as a covariate and farm and room were included as random factors in the model. Interactions between treatment and farm were non-significant, so this interaction term was removed from final fitted models. Mortality was analysed in a logistic regression using the procedure GENMOD in SAS (chi-squared ($\chi^2$) values were generated as the test statistic).

Pen hygiene data were analysed at the pen level (14 pigs). Of the 1788 records collected, only 1200 could be used after pens with fewer than 14 pigs were excluded. The occurrence of faecal contamination in the experimental pens was analyzed in an ANOVA with the procedure MIXED in SAS with days since the start of the trial as covariate (F ratios were generated as the test statistic). The number of pens which had contamination of the solid floor area, the number of pens requiring manual cleaning, the cleanliness of the slatted floor and pig cleanliness were analyzed in a logistic regression analysis using the procedure GENMOD in SAS with age of the pigs as covariate (chi-squared ($\chi^2$) values were generated as the test statistic).

### 3. Results

#### 3.1. Production data

Production results are presented for each farm separately as farm had a statistically significant impact on production results (Table 2). Farm B, had a lower daily gain and a higher feed conversion compared with Farm A. There was a small but significant difference between the two farms in carcass lean meat yield (as a percentage of live weight), but no difference between treatments. For all production data, there was no interaction between farm and treatment, so data for both farms was analysed together. Space allowance had no effect on feed efficiency, or on daily gain, although there was a non-significant tendency ($p=0.07$) for daily gain to be lower in the 0.67 m²/pig treatment than in the pens with more space.

Mortality was low (Table 2), but was significantly higher in Farm B. There was no difference in mortality between the three space allowance treatments. Mortality
figures include both euthanized pigs and pigs that were found dead. Only a few pigs needed veterinary attention (0.6 % of the pigs in both farms) due to leg, gut or tail biting problems. In total, there were 79 pens (30 of 0.67m²/pig, 26 of 0.73m²/pig, 25 of 0.79m²/pig), where one or more pigs died or had to be removed due to illness.

3.2. Pen hygiene
A summary of the 1200 measures of pen hygiene relating to the solid-floored lying area are shown in Table 3. Results for the two farms are presented separately, as there were significant differences between farms. There was no difference between treatments in: the percentage of faecal contamination, the number of pens requiring manual cleaning or in the number of 100% dirty pens. However, values of these measures increased over time as the pigs aged.

3.3. Economic Indicators
The gross margin per pig was higher in Farm A than in Farm B (p< 0.0001) due to the lower daily gain and feed efficiency in Farm B (Table 2). Neither Farm A nor B showed a significant effect of stocking density on the margin per pig. However, that there was a trend (approaching significance, p = 0.06) towards a higher gross margin per pig by increasing the area from 0.67 m²/pig to 0.73 or 0.79 m²/pig (Table 2).

4. Discussion
4.1. Production data
There were some differences in production between the farms: In Farm A, both lean meat and daily gain were higher, which could be because this farm produced both female and entire male pigs, as opposed to Farm B which produced female and castrated pigs.

There was no significant effect of space allowance on feed conversion, mortality, meat percentage, or production value. There were non-significant tendencies for improved daily gain (p = 0.07) at the two higher space allowances.

The lack of an effect of space allowance on productivity could have a number of explanations. Productivity may be more affected by the availability of feeder space, which did not vary in this study. The pigs each had 34 cm at the long trough, exceeding the recommended minimum of 32 cm for pigs up to 110 kg on liquid feed (Jensen, 2009). Alternatively, the pigs may have spent too short a time at a high enough stocking density for growth to be affected by overcrowding. In a meta-analysis Gonyou et al (2006) identified a k value of around 0.317 to 0.348 as the point below which growth begins to be affected by limited space. In our smallest space allowance (0.67m² per pig), the k value would only have fallen below the higher of these two values when the pigs reached 84.5kg (weight= (A/k)³/² = (0.67/0.0348)³/²), which was close to the finish weight of around 90kg, and would not have fallen below the lower value until 97.2kg. Gonyou et al (2006) recommended to record intermediate weights in future studies to better determine the threshold of space affects on growth.
This would have been interesting in the present study, but the nature of our study which involved large numbers of pigs on commercial farms made this impractical.

Reduced animal production can be used as an indicator of poor welfare, although it is not the most sensitive measure (Fraser, 2008), since productivity may be good in circumstances where the welfare is reduced. For example, the forthcoming EU ban on stalls for pregnant sows is to allow sows behavioural freedom and is not expected to enhance their reproductive output (Harris et al., 2006). Increased space allowance may result in improvements in aspects of welfare other than those measured in this study, such as the ability of pigs to lie down in comfort as much as they would like (Averos et al., 2010), or in reductions in tail biting or aggression or an improved immune response (Beattie et al., 1996; Turner et al., 2000; Leek et al., 2004).

4.2. Pen hygiene

Overall, both farms had a very low incidence of faecal contamination and good pen functioning in terms of a clean solid-floored lying area, in comparison with a recent study of part-slatted pens in nine other similar herds in Denmark (Pedersen, 2011). We made additional investigations of the construction of the rooms used in the present study. In Farm A, 50 mm of insulation (glass wool, type Isover 320) was present, although construction drawings showed that there should have been 100 mm insulation. A smaller insulation thickness can result in increased air inflow speed which may contribute to reducing the incidence of faecal soiling on the solid floor (Aarnink et al., 2006; Pedersen, 2011). In Farm B, air inflow speed increased during the warm periods, because the windows in the buildings were used as additional air intakes, which may also have contributed to a lower incidence of faecal soiling. The study lasted for eighteen months and so the effect of seasonal temperature variations should not have affected the results.

There were no significant effects of space allowance on pen hygiene, although the smallest pens were numerically worse than the two larger sizes. In contrast, there was a clear age/size effect. As pigs’ age increases, this decreases their upper critical temperature, due to their increased size and increased feed intake. Therefore, the pigs try to cool themselves by wallowing because they are unable to sweat, and wet areas of the pen dirty with faeces are the preferred location for wallowing (Aarnink et al., 1997; Aarnink et al., 2006). In one study, wallowing behaviour began at a room temperature of 19-20°C for pigs of 60-70kg (Huynh et al., 2005). Although wallowing is seen as a problem by the farmer, it is a natural adaptive behavioural response of the pig to cope with high temperatures (Bracke and Spoolder, 2011; Bracke, 2011), although wet faeces might not be the pigs ideal choice of wallowing substrate.

Although we showed that space allowance at a certain group size did not affect pen hygiene, group size and floor type are important: In a previous trial (Jensen, 2003) we found that a larger group size (33 - 42 rather than 17-21 pigs/pen) at the same space allowance per pig resulted in more dirty and wet pigs and that 2/3 solid floored pens were messier than 1/3 solid floors. The present study had a constant group size (14 pigs per pen) and floor type (1/3
solid), chosen to be representative of typical Danish finisher facilities. It is possible that space allowance might influence pen hygiene at different group sizes or in other pen types. Also, this study deliberately focussed on a narrow range of (commercially-relevant) space allowances (varying by only 18%). Larger effects on pen hygiene may be seen at smaller or greater space allowances.

4.3. Economic Indicators

There was a non significant tendency for a higher gross margin per pig at the two higher space allowances ($p = 0.06$). If pen cleanliness had differed with space allowance, a reduced labour requirement (the need for manually cleaning pens) might have improved the economic performance of the higher space allowance systems, helping to compensate for the reduced number of pigs. However, in this study there were no significant effects of space allowance on cleanliness.

Even in studies which do find that the production and economic measures per pig improve with increased space allowance, the production per unit area or at a system level often still declines (Edwards et al., 1988; Gonyou et al., 2006). These opposing drivers mean that the optimum from the pig and producers’ perspective are different. If policy makers make changes that benefit pig welfare for example by increasing space allowance, this can result in reduced margins for producers, unless they can obtain a price premium (Bornett et al., 2003). If rule changes occur at the same time across the EU and are enforced in all countries, then there is a level playing field within the EU, although different standards exist outside the EU. Australian space allowances are similar to those in the EU (http://www.dpi.qld.gov.au/27_11340.htm), while recommendations in Canada and the USA (Gonyou et al., 2006) are around 15% larger than those in the EU but are not enforced by law. The World Organisation for Animal Health (OiE, www.oie.int) is seeking to develop globally agreed standards.

4.4. Conclusion

At the three levels compared in this study, space allowance per pig had no effect on feed efficiency, lean meat percentage, or production index. There was a non-significant tendency for a higher daily gain and a higher gross margin per pig from an increased space allowance above 0.67m$^2$/pig. Both farms showed a very low incidence of faecal soiling and a good pen function. Pen hygiene was not affected by space allowance, but was affected by the age of the pigs. Proposals to improve pig welfare by increasing space allowance to 0.79m$^2$/pig (EFSA AHAW panel, 2005) would be costly for producers.

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