Health, Welfare, and Productivity of Pigs Housed Under Specific-Stress-Free Conditions in Comparison with Two-Site Systems

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ABSTRACT: This study describes the effects of housing pigs under optimal climatic conditions in a Specific-Stress-Free (SSF) housing system on health, behavior, immunological responsiveness, and production performance of 78 pigs from 10 litters. Pigs housed in an SSF system, where they were neither mixed nor transported, were compared with a control group of pigs for which transport was simulated and which were mixed at approximately 25 kg; transportation to another location and mixing are usual procedures in two-site systems. The SSF pigs had a higher growth rate for the finishing period (P < .01), but this was a smaller improvement in performance than in previous studies, probably due to less mixing in this study. Clinical signs were hardly seen in the SSF group, but aggression after mixing caused ear lesions in the control group. Pigs that were not mixed had a higher response 12 and 18 h after an intradermal injection of phytohemagglutinin (P < .001) compared to the control pigs. At 1 d and 1 mo after mixing the control pigs, more agonistic interactions were seen in these pigs compared with the SSF pigs (P < .05 and P < .01, respectively). In conclusion, health, welfare, and production performance of pigs are improved when pigs are kept in an SSF housing system where they are not mixed or transported.

Key Words: Pigs, Housing, Production Performance, Health, Cell Mediated Immunity, Behavior


Introduction

Recently, the general structure of housing pigs has become a subject for discussion. So far, in most countries, pigs are produced in a two- or three-site system from birth to slaughter. In a recent study in our department it was shown that the farrow-to-finish system, with pigs raised in the same pen from birth to slaughter, is a good alternative for housing pigs, with positive effects on health, productivity, and welfare (Ekkel et al., 1995b). This farrow-to-finish principle is the basic idea of the Specific-Stress-Free (SSF) system, a system of housing pigs whereby stress is prevented or minimized (Scheepens et al., 1990). Research carried out elsewhere seems to confirm the results presented in the publication mentioned above (Martinsson and Olsson, 1994).

The present study was designed to study the health, behavior, and production performance of pigs housed according to the SSF principle. However, in contrast to the earlier study (Ekkel et al., 1995b), a comparison between the SSF system and a two-site system where pigs are transported and mixed once at approximately 25 kg was made in this study.

Materials and Methods

Housing and Animals. One week before farrowing, 10 conventional, pregnant sows (Dutch Landrace × Yorkshire or [Dutch Landrace × Yorkshire] × Yorkshire) from the University's commercial farm were transported to a climate-controlled pig house (Tielen, 1986). They were randomly divided between two identical rooms. The rooms consisted of five pens of 5.6 m² each, with 2/3 slatted floors and a removable farrowing-crate. Parturition was induced by the injection of 2 mL of Planate (synthetic prostaglandin, Coopers Agrovet, Haarlem, The Netherlands) on d 114 of gestation. All sows farrowed within four consecutive days and the day of the first parturition

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was designated d 0 of the experiment. In total, 104 pigs were born alive and nine were born dead. The average birth weight was 1266 ± 25 g. Eight pigs died before d 10. At d 10, 16 pigs were removed because the pen size allowed only eight animals to be housed until slaughter (.7 m²/animal, Dutch Animal Health and Welfare Legislation). Furthermore, one animal died before weaning, and therefore 79 pigs were alive at weaning. At d 84, one pig died as a consequence of an intestinal torsion. Boars were castrated and all tails were cut on d 5. Pigs were given access to normal commercial feeds ad libitum from d 10 until 25 kg (18% CP, 1.1% lysine [L], 9.5 M J of NE/kg), from 25 until 40 kg (17.2% CP, .98% L, 9.3 M J of NE/kg), and from 40 kg until slaughter (16.1% CP, .85% L, 8.8 M J of NE/kg). Water was available for ad libitum consumption from nipple drinkers throughout the experiment. Ten 58-W tubes provided lighting from 0700 to 1700.

**Experimental Design.** The pens with pigs were randomly divided into two groups of five pens. One group was housed in “a pen from birth to slaughter” scheme according to the SSF idea. The other group, which was called the control group, was exposed to transportation and mixing at d 62. Both SSF pigs and control pigs were housed in each room. The pen with seven pigs was an SSF pen and the pig that died at d 84 in another pen was also an SSF pig. In the morning of d 62, the pigs of the five control pens were loaded into a truck and transport was simulated by driving around for 1.5 h. After transportation, the pigs were mixed and replaced into the five pens they came from. To make sure that the average weight and standard deviation of the mixed pens was comparable to that of the SSF pens, these 40 pigs were blocked into eight blocks by weight. Pigs of each block were then randomly assigned to five pens after transportation. Pigs were vaccinated i.m. for Aujeszky's disease at 74 and 97 d with a gE negative vaccine. All pigs were slaughtered when their live weight was approximately 108 kg.

**Climatic Conditions.** The climatic conditions in both rooms were thermoneutral and were therefore considered optimal for the entire experiment (Verstegen et al., 1987). The temperature was identical in both rooms and diminished weekly by 1°C (22 to 18°C in the farrowing period, 26 to 22°C during the rearing period until d 62, and 22 to 18°C in the first weeks of the finishing period). Relative humidity was kept at 70% throughout the experiment. The environmental temperature and relative humidity were recorded continuously for each room. The water temperature of the floor heating system in both rooms was set at 45°C at farrowing, which resulted in a contact temperature of the concrete floor of approximately 30°C. This temperature was gradually reduced, based on the lying behavior of the pigs. After 2 wk the floor heating system was turned off. The climatic conditions were checked each week according to the following parameters: air velocity (m/s); katavalue (as a parameter for the chilling effect of the air in milliwatts/square centimeter; Janowski, 1977); CO₂ (volume percentage), and NH₃ concentration (parts per million).

**Measurements.** Throughout the experiment, the pigs were weighed individually every week. Feed intake was recorded per pen each week, and feed conversion (feed:gain ratio) was also calculated weekly. Before each weighing procedure one pig per pen was randomly chosen and its feces were collected during weighing. This was done without disturbing the pig, because pigs frequently defecated during the weighing procedure. Moreover, feces of pigs that deviated from normal as regards to color and consistency were collected. All feces samples were checked for Escherichia coli, Serpulina hyodysenteria, and Salmonella spp. bacteria as described elsewhere (Ekkel et al., 1995b). Occasionally, pathogenic E. coli could be isolated. At d 82, four pigs were positive for Serpulina hyodysenteria for the first time. Furthermore, some clinical diarrhea was seen by that time. Weekly, two to eight pigs were positive until d 109. Positive pigs were found in both rooms and came from both groups.

Blood samples were taken from a random selection of 42 pigs on d 60 and at the slaughterhouse. Serum was frozen until it was analyzed for antibodies against Actinobacillus pleuropneumoniae (type 2 and 9), Aujeszky's disease (gE positive), and Influenza (H1N1 and H3N2). Analyses of blood samples at the slaughterhouse showed that these pigs were all negative for Actinobacillus pleuropneumoniae Influenza, and Aujeszky's disease (gE). Moreover, clinical symptoms of these diseases were never seen. Clinical observations were performed daily as described elsewhere (Ekkel et al., 1995b), except for the registration of coughing and sneezing during 10 min in each room, for experimental groups were present in both rooms.

**In Vivo Cell-Mediated Immunity.** The phytohemagglutinin (PHA) skin test was performed as described by Ekkel et al. (1995a). This test was done on d 57 and immediately after mixing (d 62). Phytohemagglutinin (250 µL, Sigma, L8754) dissolved in .1 mL of sterile Eagle's Minimal Essential Medium (MEM, Flow Laboratories, Irvine, U.K.) was injected intradermally in the middle of two circles with a diameter of 2 cm that were stamped on the left and right side of the ventral abdomen. The skinfold thickness was measured before injection and 6, 12, 18, 24, 36, and 48 h after injection with a spring action cutimeter (Aesculaap VA 110, Vetin-Aacopharma BV, Boxtel, The Netherlands). Data were expressed as absolute increase in skinfold thickness (6, 12, 18, 24, 36, or 48 h thickness minus pre-injection thickness). An average per pig was calculated based on the two tests on each pig. The skin test was performed on 18
pigs from each group. These pigs were chosen randomly.

Behavioral Measurements. The agonistic behavior of the pigs was quantified by direct observations using a tape recorder. The following agonistic interactions between pigs were recorded in this experiment: fighting, biting, headknocks, pushing, chasing, replacing, threatening, and submissivity. Pigs were observed immediately after transporting and mixing the control group (Series one, d 62 and d 63) and on d 7 in the finishing period (Series two, d 96, 101, 102, 103, 109, 110, and 112). The observational periods of each day were 0930–0955, 1030–1055, 1130–1155, 1300–1325, and 1400–1425, except for d 62, when pigs were transported in the morning and then mixed. Here, behavior was measured from 1445–1510, 1515–1540, 1615–1640, and 1645–1710. During each observational period of 25 min the pens of each room were observed at random (determined by Latin square) for 5 min. Behavioral observations were carried out in both rooms at the same time by two observers, who changed between rooms after each observational period and who started in another room each day. Data were expressed as the total agonistic score (the sum of all recorded agonistic interactions) per observational period per pen.

Statistical Analysis. The SAS statistical package (SAS, 1988) was used for all statistical calculations. To examine the assumption of normality, the Wilk-Shapiro (Shapiro and Wilk, 1965) procedure was used. All variables presented conformed to a normal distribution. Differences of growth performance and increase in skinfold thickness after the intradermal injection of PHA at d 57 and d 62 between both groups were analyzed using a multivariate repeated measurements ANOVA. Weekly weights and 6 h measurements of skinfold thickness were used for this analysis, respectively. In the model used in this analysis, sex, pen, group, and all interaction terms were included. Average daily gain, feed intake, and feed conversion rates on pen-level and differences in delta skinfold thickness at each of the time points at d 57 and d 62 were tested using a two-sample t-test, comparing the treatments. The chi-square test (Siegel and Castellan, 1988) was performed to evaluate differences in occurrence of clinical signs. A general linear model procedure was used to test differences in total agonistic score within each series. For each of the two series, time of the day, day of measurement, group (control and SSF group), observer, and interaction terms were included in the model.

Results

Climatic Conditions. The environmental temperature of both rooms was in accordance with the values set, except for d 86 to d 88 and d 93 to d 94, when the temperature was on average 6°C above the value set in both rooms. During these days, the environmental temperature exceeded thermoneutral conditions. The reason for these high temperatures was a mechanical failure of the cooling unit of the facility. Relative humidity was always between 60% and 80%. Twenty-four weekly measurements of CO2 and NH3 concentrations showed an average of .22 and .21 vol.% CO2 for each of the two rooms and 5.8 ppm NH3 for both rooms. Average air velocity on the lying area of the pigs never exceeded .15 m/s. Mean katavalues per room were 23.1 and 23.7 mW/cm².

Production Performance. Both for the farrowing period and the rearing period, no differences (P > .05) in growth were found between the pigs in the two groups. Figure 1 represents growth data of both groups of pigs for the finishing period. The repeated measurements analysis of variance revealed a significant group × time interaction (P < .01), indicating that the SSF line is more steep. Table 1 represents the average daily gain data, based on weights at d 62 and d 150. No difference could be detected here (P > .05). The results for the finishing period, as they are presented in Figure 1 and Table 1, represent figures until d 150; on this day, 38 pigs from different pens and groups were slaughtered, so the experimental conditions differed from that moment on.

Clinical Variables. No appreciable clinical signs were seen in the farrowing and the rearing period; some pigs in both groups had ear lesions caused by social interactions in the first weeks. Lesions on the legs were seen incidentally. After the pigs of the

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>SSF</th>
</tr>
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<tbody>
<tr>
<td>Live wt on d 62, kg</td>
<td>28.5 ± .7</td>
<td>28.6 ± .7</td>
</tr>
<tr>
<td>CV d 62b</td>
<td>14.9 ± 1.8</td>
<td>14.1 ± 2.3</td>
</tr>
<tr>
<td>Average daily gain, g/d</td>
<td>812 ± 14</td>
<td>840 ± 13</td>
</tr>
<tr>
<td>Feed intake, g/d</td>
<td>2,209 ± 47</td>
<td>2,275 ± 43</td>
</tr>
<tr>
<td>Feed conversion rate, kg/kg</td>
<td>2.72 ± .04</td>
<td>2.72 ± .07</td>
</tr>
<tr>
<td>Live wt on d 150, kg</td>
<td>100.0 ± 1.58</td>
<td>102.7 ± 1.48</td>
</tr>
<tr>
<td>CV d 150b</td>
<td>9.3 ± 3.3</td>
<td>10.1 ± 4.1</td>
</tr>
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a To calculate feed conversion rates on pen-level, growth figures of all pigs per pen were used (n = 5).

b Average coefficient of variation of live weight within the five pens of each group.
control group had been transported and mixed, fewer hemorrhagic lesions of the auricle were seen in the SSF group compared to the control group ($P < .05$, Table 2).

In Vivo Cell-Mediated Immunity. After the injection of PHA on d 57, the in vivo cellular immune reactivity was the same for both groups of pigs. However, on d 62, the immunological reactivity of the two groups differed (Figure 2). The reactivity at 12 and 18 h after injection at d 62 was higher for SSF pigs than for control pigs ($P < .001$). With a repeated measurements analysis of variance, a significant group $\times$ time interaction was found ($P < .01$), whereby the response of the SSF pigs was quicker and higher than that of the control pigs.

Behavioral Measurements. In the control group, total agonistic score for Series one was higher than that for the SSF group (59 vs 23.8, $P < .05$, Figure 3). Other main factors or interaction terms did not contribute to the differences found ($P > .05$). For Series two, there was still a difference between the two groups; total agonistic score was higher for mixed pigs than for SSF pigs (158.4 vs 87.2, $P < .01$). Apart from this group effect, time of the day contributed to the variance observed ($P < .05$) in Series two, whereby pigs tended to be more active in the morning than in the afternoon.

Discussion

Health and welfare of domesticated animals have received a lot of attention the last few decades, especially intensively housed animals such as finishing pigs that are exposed to many factors that affect their homeostatic balance, such as crowding, moving, regrouping, suboptimal climate, and bad handling. In an earlier study, Ekkel et al. (1995b) showed that health, welfare, and production performance of pigs were improved when pigs were housed in the same pen from birth to slaughter under optimal climatic conditions, which is the basic idea of the Specific-Stress-Free (SSF) housing system (Scheepens et al., 1990). In contrast with that study, the present paper describes an experiment in which the SSF system is compared with a two-site system. Here, the control pigs were only transported and mixed at 25 kg. In practice, this is identical to the transport from the multiplier farm to the finishing farm and the formation of groups that are uniform with regard to their weight.

The difference in average daily gain for the finishing period found in this study was too small to be detected with the two-sample $t$-test. However, the group $\times$ time interaction demonstrated with the more accurate repeated measurements analysis based on weekly weight data, made clear that both groups did grow in a different way; the growth line of the SSF pigs is steeper, so they grew faster and they reached their slaughter weight earlier. In any event, simulating transportation for 1.5 h and mixing pigs afterward affects growth performance to a small degree. It is difficult to determine whether these small effects were caused by the 1.5-h transportation procedure or by mixing the pigs. Rundgren (1988) found only short-term differences in growth between pigs that were transported and mixed compared to pigs that were

<table>
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<tr>
<th>Clinical sign</th>
<th>Control</th>
<th>SSF</th>
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<tbody>
<tr>
<td>Auricle Hemorrhagic lesions$^b$</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Scratches</td>
<td>29</td>
<td>24</td>
</tr>
<tr>
<td>Flank and shoulder</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Scratches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legs</td>
<td>3</td>
<td>2</td>
</tr>
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$^a$Figures represent the average total number of animals registered per sign for the control group (n = 40) and the SSF group (n = 38).

$^b$Difference between the two treatments was significant for this item ($P < .05$).
Figure 2. The increase in skinfold thickness after an intradermal injection of three different doses of phytohemagglutinin (PHA) dissolved in .1 mL Minimum Essential Medium. Solid bars + SE represent SSF pigs (n = 18) and hatched bars + SE represent control (mixed and transported) pigs (n = 18). ***P < .001.

Figure 3. Total agonistic score of the two experimental groups + SE. Averages of the five pens of each of the two groups are given for each of the Series one and two. Series one concerns observations on d 62 and 63. Series two are observations carried out on d 96, 101, 102, 103, 109, 110, and 112. *P < .05, **P < .01.
mixed only, but the performance of that latter group of pigs in her study might have been affected by the fact that these were moved to another facility, too (Mardarowicz, 1985). Productivity of mixed pigs was decreased in the experiments of Hessing et al. (1994), which were carried out in the same experimental rooms. Therefore, the contribution of transportation to the described effect is probably small.

Apparently, the degree to which growth is affected strongly depends on what pigs have experienced in the past; the effects of transporting and mixing at 25 kg is more harmful for finishing pigs when they are mixed at weaning also (Ekkel et al., 1995b) than when they are not, as the present study shows. Therefore, a new aspect can be added to the conclusion of Sherritt et al., (1974), who stated that the effect of mixing probably depends strongly on additional stressors; former experiences seem to be important also. In studies described in monkeys (Terao et al., 1995) and red deer yearlings (Hanlon et al., 1995), repeated alterations of group composition seemed to result in significant social stress. Hence, it is more likely that repeatedly regrouping animals leads to sensitization (higher responses after successive exposure to stimuli) and not to habituation (waning of the response, see Broom and Johnson, 1993).

The behavior of pigs when they are mixed with unacquainted penmates has been well described (McBride et al., 1964; Fraser, 1974; McGlone, 1985; reviewed by Fraser, 1983–1984). Most studies describe vigorous fighting after a short period of exploration, but 48 h later hardly any fights are seen and the social hierarchy is supposed to be established (Friend et al., 1983; Rushen, 1987; Rundgren, 1988). One study observed high levels of fighting beyond the 48 h after regrouping (Stokey and Gonyou, 1994). However, these studies do not examine the less intense mutual chronic aggression. This mutual chronic aggression might affect growth rate more than does the intense fighting shortly after pigs have been mixed (Rushen, 1987). Hence, it was not surprising that in the present study, more agonistic interactions immediately after mixing (Series one) were observed between pigs in groups that were transported and mixed compared to the SSF pigs. In addition, a higher level of mutual aggression was found in transported and mixed groups of pigs in Series two, which was more than 1 mo after mixing. Fraser (1984) points out that this type of chronic conflict is influenced by the amount of floor space available, perhaps group size, and other factors that cause restlessness and physical discomfort. The present study shows that mixing is one such factor that increases chronic mutual aggression.

Differences in clinical signs were only found for the incidence of hemorrhagic lesions of the auricle. Particularly in the first weeks after transportation and mixing of the control group, more lesions were seen in these pigs, which is in agreement with former studies (Rundgren, 1988; Ekkel et al., 1995b) and in line with the findings that more agonistic interactions were found after mixing. McGlone (1985) showed that when pigs are regrouped, agonistic interactions such as bites are targeted mainly at the ears, face, and neck, causing scratches and other injuries. It is possible that diseases can enter the body through these lesions more easily.

The relationship between mixing, consequent aggression, and production performances of pigs has been a subject of discussion before (Friend et al., 1983; Rushen, 1987). The study by Ekkel et al. (1995b) and the results of the present study have shown that transporting and mixing pigs have negative effects on health, welfare, and production performance of pigs in comparison with pigs housed in the same pen from birth to slaughter. The degree to which mixing influences aggression, and possibly production performance, depends on the variation in weight between both groups (Tindsley and Lean, 1984; Rushen, 1987). There was no difference between both groups in the variation in weight around the mean within the five pens of each group (coefficient of variation) in this study, neither at mixing nor at d 150. In practice, farmers are often advised to ensure that the pigs are matched by weight when mixing. This definitely induces higher levels of aggression and the effects on production performance probably will be more detrimental.

The results of the skin test, in which the cellular immune reactivity of the pigs was tested after an intradermal injection of PHA, confirm the results described elsewhere (Ekkel et al., 1995a); again, the reactivity of stressed pigs is delayed and the peak level is not as high as that of SSF pigs. Moore et al. (1994) found a decreased reactivity in the PHA skin test as a result of regrouping 8 h after injection, but no difference was found 24 h after injection of PHA. These consistent results confirm that stress induces a reduction of the immunological reactivity to an intradermal injection of PHA. Moreover, these results make clear that frequent measurements give a better picture of the cellular immune reactivity of pigs in the PHA skin test than single measurements do. Perhaps under certain circumstances such as repeated or more violent exposure to stress, differences between stressed and unstressed controls are greater and can be detected when measured at 24 h also. However, one measurement 24 h after the injection of PHA, which is frequently described in pigs (Blecha et al., 1983, 1985; Hessing et al., 1995), should be advised against before this is more clear.

In summary, health, welfare, and production performance of pigs are improved in a system in which pigs are housed in the same pen from birth to slaughter. The degree to which transportation and mixing at 25 kg live weight leads to a decreased production
performance in the finishing period depends on earlier stress experiences. Besides the number and nature of these stressors, the time span between them has to be taken into account.

**Implications**

In comparison with a two site system in which pigs are transported at 25 kg and regrouped at the finishing unit, health, welfare, and production performance of pigs are improved when pigs are housed according to the Specific-Stress-Free system in which they stay in their pen from birth to slaughter. The improvement in performance was smaller in comparison with previous studies, probably due to less mixing in this study. It is therefore worthwhile to aim at applying housing systems for pigs in which stress is prevented or minimized according to the principles of this Specific-Stress-Free system.

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