Animal 18 (2024) 101086

Contents lists available at ScienceDirect

Animal
The international journal of animal biosciences

Effects of socialising piglets on sow and piglet performance and behaviour of entire male piglets

L. Rydhmer [a,*], K. Andersson [b]

[a] Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, Box 7023, 75007 Uppsala, Sweden
[b] Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Box 7024, 75007 Uppsala, Sweden

ARTICLE INFO

Article history:
Received 4 July 2023
Revised 15 January 2024
Accepted 19 January 2024
Available online 26 January 2024

Keywords:
Aggression
Nursing
Pig
Socialisation
Health

ABSTRACT

Entire male pigs show more aggressive behaviour and mounting than female pigs. By sorting growing pigs into male and female pens, at least half of the pigs are protected from the aggressive behaviour and mounting of the entire males. Mixing of unknown pigs provokes them to perform such behaviours which increase the risk for injuries. The idea behind socialising piglets is to create groups of piglets from several litters that become familiar with each other and thus show less aggressive behaviour and mounting later, when housed together after weaning. The effect of socialising piglets on animal welfare was studied on 24 sows and their 235 piglets. Male piglets were not castrated. Sows were housed in individual farrowing pens without crates. A small door was opened between two adjacent pens at a piglet age of two weeks for half of the litters (12 litters), and the other half was regarded as a control (12 litters). At weaning, control piglets were kept in groups of eight litter mates whereas socialised piglets were kept in groups of either eight entire males or eight females from two litters. Sow weight, body condition and health were recorded together with nursing events and social behaviour of piglets (aggressive, mounting, contact). There was no effect of socialisation on udder lesions or sows' relative change in body reserves. Socialised and control piglets did not differ in daily weight gain before weaning, but socialised piglets tended to have higher growth rate during the week after weaning (P = 0.07). The day after opening between pens, skin lesions were more common among socialised piglets (as compared to control piglets at the same age, P = 0.02) but at weaning, skin lesions were more common among control piglets than socialised piglets (P = 0.01). Almost all lesions were mild. No aggressive behaviour of sows towards piglets was observed. No difference between control and socialised piglets in social behaviour was seen before weaning. The frequency of aggressive and mounting behaviours was low after weaning for both socialised and control piglets, but socialised piglets showed more contact behaviour (P = 0.02). Socialised entire males showed as little aggressive and mounting behaviour as females. Nursing frequency was not affected by piglet socialisation and cross-suckling was rare. Based on the performance of piglets and sows, nursing frequency, and health of piglets and sows, we conclude that socialising entire male piglets (and their sisters) improve piglet welfare without any negative effect on the sows.

Implications

Entire male pigs show more aggressive behaviour and mounting than female pigs. Mixing of pigs from different litters generally provokes these damaging behaviours, but piglets from two litters can become 'socialised' by a small opening in the wall between farrowing pens. Socialised piglets do not need to fight when housed together at weaning. In this study, cross-suckling was rare and did not cause problems when piglets were socialised. Socialising piglets is a routine that can improve piglet welfare without any negative effect on the sows. This routine can facilitate the ending of castration in pig production.

Introduction

In most countries, male pigs are castrated in order to avoid boar taint (von Borell et al., 2020). Surgical castration is painful and the European food safety authority panel on animal health and welfare states that there is a need for alternatives to surgical castration and one alternative is to rear entire males (Nielsen et al., 2022). Some welfare problems are, however, associated with the rearing of entire males since they perform more aggressive and sexual beha-

* Corresponding author.
E-mail address: Lotta.Rydhmer@slu.se (L. Rydhmer).

https://doi.org/10.1016/j.animal.2024.101086
1751-7311/

viour than castrates and females (von Borell et al., 2020). Mixing with unknown pigs is stressful for all pigs, but the negative consequences of mixing are more severe with entire males than with castrates, as entire males fight more during rearing (Rydhmer et al., 2010). Ideally, entire males should thus be reared in intact litter groups to increase their welfare (Fredriksen et al., 2008). On the other hand, housing entire males together with female siblings can be questioned as it may result in mating and slaughter of pregnant females (Bünger et al., 2014). Housing males from only one litter in each pen until slaughter would result in small groups (around six males) and increase rearing costs above accepted levels. In this study, we aimed for a cheap and simple way to create groups of familiar entire males with a group size appropriate for conventional growing–finishing units. According to a farmer survey, preweaning socialisation has low monetary costs (Peden et al., 2021). Therefore, we let piglets from two litters socialise by meeting at a young age, and separated them into male and female groups at weaning. These socialised piglets were compared to a control group of piglets reared with only litter mates.

Pigs are social animals, and the social unit in populations of wild boars and feral pigs includes a sow and its litter. Several such families form groups of around a dozen animals. Males leave these groups at puberty and are thereafter solitary animals except during breeding season, when they approach the sows (Allwin et al., 2016). If male wild boars meet, they show aggressive behaviour and their intensive fights lead to injuries and sometimes death (Allwin et al., 2016). The home range area is variable and in general larger for males than for females. Friebel and Jodice (2009) reported 2 km^2 for feral pigs and according to Allwin et al. (2016), more than 10 km^2 is a common size for wild boars. Thus, a conventional pig pen, with its limited size, high stocking density and mix of pigs from different families, is far from the natural environment for wild boars, especially for males.

The base for piglet socialising is that there is one period in pigs' life when mixing is not associated with fighting. That is at 10 to 14 days of age, when a sow kept under 'natural conditions' leaves the isolated farrowing nest and brings its piglets to the group (Jensen and Redbo, 1987). A decade ago we (Rydhmer et al., 2013), and our colleagues (Fàbrega et al., 2013) working on the EU project called Q-PORKCHAINS, reported that socialising piglets and keeping intact groups during the growing-finishing phase and at slaughter improved the welfare of entire male pigs. Since then, additional studies have confirmed the beneficial effects of socialisation on pig welfare after weaning (Ji et al., 2021; Camerlink et al., 2018; Salazar et al., 2018). Less articles focus on the sows of socialised piglets, and studies on socialisation of piglets with louse-housed sows in individual farrowing pens are scarce. Therefore, we have now returned to unreported data from the study by Rydhmer et al. (2013). In this article, we show the effects of piglet socialising on nursing behaviour and body condition of sows, and behaviour and growth of piglets during lactation and at weaning.

Material and methods

Experimental design

A total of 24 Swedish Yorkshire sows in parity 1 to parity 11 (mean 4.1, SD 2.9) and their offspring were used in this study. The study was performed from 2010 to 2011 at the Swedish Livestock Research Center Lövsta, in accordance with Swedish regulations for the use of pigs. The sires of the piglets were randomly selected from Swedish Yorkshire sires available for artificial insemination. Each sow and its piglets were kept in a farrowing pen without a crate (according to Swedish standards). The sow was moved to the farrowing pen approximately seven days before expected farrowing. The sows were located in pens based on expected farrowing date so that sows farrowing close in time were housed in adjacent pens. Cross-fostering was avoided, but necessary in a few litters to achieve at least four vital male piglets in each litter for a subsequent growing-finishing study. The results from the study of growing-finishing pigs have been reported elsewhere (Rydhmer et al., 2013).

A total of 235 piglets from 24 litters were included in this study. Of these, 11 piglets were raised by a foster sow and these piglets were moved to the foster sow at an age of 0–2 days. In this article, 'litter mates' refer to piglets raised by the same sow. Piglets were not castrated, and tail-cutting was not performed. The piglets were weaned at an age of five weeks (33–36 days). Average litter size at weaning was 9.8 piglets (SD 1.4). At weaning, 43 piglets were moved to another unit so that each group consisted of eight piglets. When there was a surplus of piglets, weak piglets and very small and very large piglets were taken away, resulting in groups of eight average-sized and vital piglets for the subsequent study (reported by Rydhmer et al., 2013). Weaning was performed by removing the sow from the farrowing unit.

Two treatments were compared. In one, piglets from two litters were allowed to meet each other through an opening between the farrowing pens, from approximately two weeks of age (12–15 days) until weaning. The opening (40 × 40 cm) was located in the piglet corner, where the sow could not enter. Piglets from two litters in adjacent pens could thus meet and visit each other's pens (Fig. 1). At weaning, these piglets were sorted by sex so that each farrowing pen housed either eight male piglets or eight female piglets (four piglets from each litter; single-sex). The opening between pens was closed and from then on the piglets were raised in intact groups until it was time to move to the growing-finishing unit. Thus, some of the piglets stayed in their own farrowing pen and some in the pen where they had been visiting since two weeks of age. The piglets in this treatment are referred to as 'socialised piglets'. In the other treatment, control piglets were raised in their litters without meeting any other piglets. At weaning, four male and four female litter mates stayed in their farrowing pen until it was time to move to the growing-finishing unit. Note that in this study, no piglets were mixed with unknown piglets at weaning.

The farrowing pen had a feeding trough that was 0.85 m long, a water nipple, 6.55 m^2 concrete floor and a dunging area of 1.90 m^2. The piglets had access to a piglet corner of 1.36 m^2 provided with a

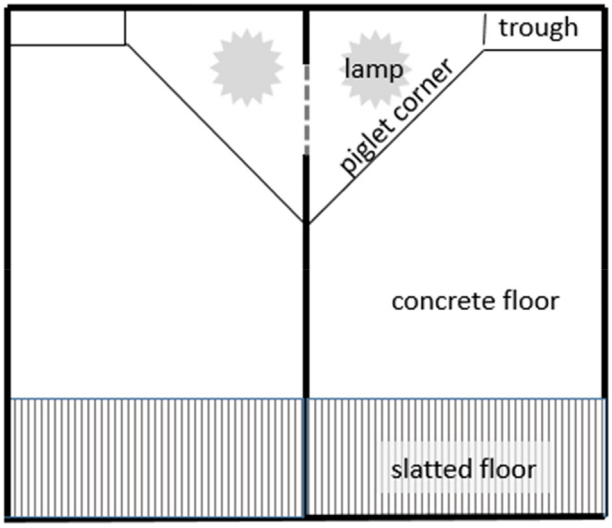

Fig. 1. Schematic illustration of farrowing pens. In Sweden, sows are not housed in crates and this pen design follows Swedish standards, apart from the opening between pens in the piglet corner. The opening is marked with a dashed line.

heat lamp. The staff monitored all pens every day and cleaned the concrete floor when necessary. The sows got straw twice a day (approx. 1 kg per pen). A standard feeding regime for lactating sows based on the number of piglets was used, and the sows were fed twice daily during the first two weeks after farrowing and thereafter three times per day. Feed was provided in the trough by an automatic fodder waggon. From 3 weeks of age, the piglets had free access to commercial creep feed from an automatic feeder located in the piglet corner. The piglets were individually weighed at 2, 3, 5 and 6 weeks of age. Sows were weighed, and backfat was recorded with ultrasound (at the last rib about 8 cm from the midline) shortly after farrowing and at weaning. The mean of backfat records from both sides was used in the analysis. Litter growth from birth to weaning was studied as an indicator of sows' milk production (Noblet and Etienne, 1989). Piglet weight homogeneity at weaning was calculated as within-litter SD of weaning weights. Records of weight and or backfat loss were missing for three sows that did not want to enter the scale.

Behavioural studies

Nursing events, and piglet activity and social interactions between piglets were studied by direct observations at four observation occasions per pen: one or two days before the opening between the farrowing pens (1st occasion; piglet age 10–13 days), the day after the opening (2nd occasion; piglet age 13–16 days), around two weeks after the opening (3rd occasion; piglet age 4 weeks) and the weaning day after the sow was removed from the pen (4th occasion; piglet age 5 weeks). Two observers took turns in recording behaviour in this study. They developed the ethogram and practised recording together before data collection started. Behavioural data were recorded by the observer, standing outside the pen. Observations did not start until the pigs were accustomed and no longer seemed to pay attention to the observer. For the socialised pigs, the sow and its piglets were marked with blue or green colour on the back to make it possible to identify which of the two litters each piglet belonged to.

The behavioural observations started after the morning husbandry routines were done in the stable (around 9 o'clock) and ended before the afternoon husbandry routines started (around 3 o'clock). The observations consisted of two kinds of sampling and recording performed simultaneously by the observer: instantaneous scan sampling of activity behaviours, and continuous recording of frequencies of social interactions and nursing events. Instantaneous scan samplings of activity behaviours were performed at the beginning and end of each observation round. Between these scan sampling observations, frequencies of social interactions were recorded continuously for a total of 4 min. During an observation day, two or four pens were observed and with two pens, longer pauses were taken between the rounds to spread out the observation period over the day. Before weaning, two pens with socialised piglets were observed simultaneously followed by two pens with control piglets with approx. 25 rounds at each observation occasion (approx. 5 min per round). After weaning, observations were made in the same way but on each pen separately with in total approx. 15 rounds. During an observation day, every piglet was observed with 30–50 scans and 60–100 min continuous observations, spread out during approximately six hours. If a nursing occurred in any of the two or four observed pens during this period of continuous observation, the clock was stopped in order to observe the nursing, and the observation of frequencies of social interactions was not resumed until the nursing was over. The nursing was over when at least half of the piglets had left the udder or fallen asleep.

The definitions of the behaviour parameters are presented in Table 1 (activity; suckling, resting in piglet corner, resting in pen and active) and Table 2 (social interactions; aggressive, mounting and contact). The receiver's reaction to a social interaction was recorded as no reaction, avoid, escape, and reciprocation (Table 2). Different social interactions were recorded as new events, regardless of whether they were performed by the same or different pigs. A new event was recorded as soon as new piglets interacted or when the interaction stopped for three seconds or more, and then started again.

Table 1
Definitions of piglet behaviour parameters used at the scan sampling.

Behaviour parameter	Definition
Suckling	Having a teat in its mouth, massaging udder or trying to reach a teat during suckling
Resting in piglet corner	Lying down awake or sleeping in the piglet corner
Resting in pen	Lying down awake or sleeping in the pen outside the piglet corner. Can be suckling after half of the litter has been leaving the udder or can be sleeping close to the sow's udder
Active	Standing or sitting (≥2 legs straight) and not suckling

All nursing events occurring in the two or four observed pens during the observation day were recorded regardless of in which pen nursing occurred (mean observation duration per sow 4.1 h, SD 0.60 h). The litter identity (i.e. piglets marked in green or blue) of all suckling piglets, and the location of the piglets (in the own pen or in the adjacent pen) during nursing were recorded continuously during the behaviour observations (Table 3). A piglet was considered to suckle when it was present at the udder, having a teat in its mouth or trying to reach a teat during the time of milk ejection. The time of the nursing was recorded and if two sows within a pair were nursing within two minutes of each other, these nursing events were considered as synchronised. Each nursing event was then classified as synchronised or not synchronised nursing within the pair of sows.

Skin lesions and health

Sows' and piglets' health was monitored daily, and all treatments were recorded on an individual basis. The udder of sows was inspected on the day when it was opened between pens and at four weeks. The observer entered the pen and palpated the udder and all teats on both sides. Number of mild (red skin, shallow scratch or shallow and small wound with or without crust) and severe (open wound, wound with large or thick crust or infected wound) injuries on the udder and on the teats were recorded. Number of teats in milk was estimated by palpating

Table 2
Definitions of the piglets' social interactions during continuous recording.

Behaviour parameter	Definition
Performed behaviour	
Aggressive	Two or more piglets fighting or giving head-knocks or bites
Mounting	Mounting or trying to mount another piglet
Contact	Touching another piglet with the snout in a non-aggressive way
Receiver's reaction	
No reaction	No change in body position or activity of the receiver piglet
Avoid	Piglet turns head away or moves away from the performing piglet
Escape	Piglet runs away from the performing piglet
Reciprocation	Piglet approaches the performing piglet with its head

Table 3
Definitions of suckling behaviour and location of piglets.

Behaviour parameter	Definition
Nursing frequency	Number of nursing events with signs of milk let-down
No. of own piglets suckling	Number of own piglets having a teat in its mouth or trying to reach one
No. of other piglets suckling[1]	Number of piglets from the adjacent litter having a teat in mouth or trying to reach one
No. of own piglets in pen	Number of own piglets in the pen during nursing
No. of piglets from adjacent litter in pen[1]	Number of piglets from the adjacent litter in the pen during nursing

[1] In socialised groups.

the udder part of each functional teat, and recorded as number of filled udder parts.

All piglets were individually inspected by a technician for bite lesions on the snout and skin lesions at six occasions. The first inspection was performed the day before the opening between the farrowing pens and the second two days later. Further inspections were performed at the age of 3, 4, 5 and 6 weeks. Snout lesions were recorded as no (0 lesion); few (1–3 lesions); several (>3 lesions); all-over (covering mouth and snout area on both sides). Skin lesions were recorded as severe and mild bites and scratches at head, front and back of the piglet. 'Severe' was defined as open wound, wound with large or thick crust or infected wound. 'Mild' was defined as red skin, shallow scratch or shallow and small wound with or without crust. The number of skin lesions at head, front and back of the pig was recorded in four classes: 'no' (0 lesion); 'few' (1–3 lesions); 'several' (4–9 lesions); 'many' (≥10 lesions). These records were later translated to figures where 'no' became 0, 'few' became 2, 'several' became 7 and 'many' became 12; and the sum of these figures is called 'number of skin lesions' per pig. The records were also used to classify the piglets into two groups called 'without skin lesions' (no lesion) and 'with skin lesions' (at least one lesion). Sows were monitored for shoulder ulcers at weaning, and the severity of shoulder ulcers was recorded on this scale: 0 = no ulcers, 1 = ulcers in the epidermal layer of the skin and sometimes with crust formation, 2 = ulcers in the epidermal/dermal layer of the skin with crust formation and scar tissue, 3 = ulcers in the subcutical layer of the skin and with crust formation and 4 = deep ulcers into the muscles, sometimes with visible shoulder bone. Snout and skin lesion records were missing on the third occasion for two litters.

Statistical analyses

Data were analysed with the Statistical Analysis System, version 9.3 (SAS Institute, Cary, NC, USA). The effect of treatment on daily weight gain was evaluated with Proc Mixed. Piglet was the statistical unit and the model included the fixed effect of treatment (socialised or control piglets), sex (entire male or female piglet), litter size (total number of piglets born, three classes: <10, 10–12, >12), parity (three classes: 1, 2–6, >6) and the random effect of sow. For growth rate after weaning, number of piglets born was replaced by number of piglets weaned. All sow traits except nursing frequency were evaluated with Proc GLM. Sow was the statistical unit and the model included the fixed effects of treatment (socialised or control piglets) and parity (two classes: 1–3, >3). A preliminary analysis showed that the conclusions did not differ between a model including parity and a model including litter size. Nursing frequency was analysed with a model including treatment and observation occasions (before opening, 1st occasion, piglet age 10–13 days; after opening, 2nd occasion, piglet age 13–16 days; around two weeks after opening, 3rd occasion, piglet age 4 weeks).

Activity behaviours were recorded as the percentage of piglets performing a particular behaviour at each observation occasion (average of all scan samplings). The social behaviour was recorded as the total number of interactions performed per pair of pens during all continuous observation-periods at each observation occasion and then adjusted to number of interactions during 60 min. As the litter size differed between pens before weaning, and the number per pen after weaning was eight piglets, the frequency of social interactions was adjusted to 10 piglets per litter and pen to make it possible to compare the frequencies recorded at the different observation occasions. Pair of pens (N = 12) was the statistical unit for behaviour analyses. Behaviour parameters did not show a normal distribution of the residuals. Thus, activity behaviour data were arcsine-transformed and social interaction data were square root-transformed before statistical analysis. These parameters were evaluated within each observation occasion with Proc Mixed. The model included treatment as fixed factor and pair of pens (simultaneously observed) within treatment was treated as random. For comparisons over time (from the day before the opening between the farrowing pens until a piglet age of 4 weeks), analogous evaluation was performed within treatment, with observation occasion as fixed factor. A chi-square test with Fisher's exact test was conducted to analyse differences in the frequency of interactions directed towards litter mates in groups with socialised piglets.

The impact of treatment (socialised vs control piglets) on the number and the severity of the skin lesions was evaluated within each inspection with Proc Mixed and the model included the fixed factors of treatment (socialised or control piglets) and sex (entire male or female piglets) and the random effect of pair of pens within treatment. The effect of treatment on the occurrence of skin lesions (with or without lesions) and the occurrence of nursing synchronisation were tested as a logistic regression using a binomial distribution with a logit link function. These analyses were done with Proc Genmod and the model included the effect of treatment. The level of significance was set at $P \leq 0.05$.

Results

Performance and health of sows and piglets

Most piglet mortality occurred around birth, but two piglets died at the age of 12 days. They belonged to a control litter. One female piglet in the control group died 7 days after weaning. This piglet had breathing difficulties. No difference in the number of medical treatments was found between the two experimental treatments, neither for piglets, nor for sows. One control sow had a mild lameness at farrowing and one sow with socialised piglets was culled after weaning due to abscesses. Two sows had shoulder ulcers at weaning, classified at severity level 2, i.e. ulcer in the epidermal/dermal layer of the skin with crust formation and scar tissue. These sows were control sows. Teat and or udder lesions were recorded on two sows in total. One control sow had one teat with a mild injury and one severe injury on the udder at two weeks. At four weeks, this sow still had a mild injury on the udder. At four weeks, one sow with socialised piglets had a severe injury on the udder. There were no differences between treatments in relative weight and backfat changes from farrowing to weaning (Table 4). Within-litter deviation in piglets' weaning weight, and total litter growth during lactation did not differ between treatments (Table 4).

Daily weight gain did not differ significantly between the socialised and the control piglets before weaning (Table 5). Weaning had a negative effect on growth rate during the week after weaning for both control piglets and socialised piglets (from above 400 g/d

Table 4
Litter size at weaning, total litter growth during lactation, within-litter SD in piglet weaning weight, sows' BW and backfat thickness at weaning and relative weight and backfat loss during lactation. Results are presented as least square means with pooled SE and significance of difference between treatments (*P*-value).

		Control sows		Sows with socialised piglets		SE	*P*-value
Sow trait		n	Average	n	Average		
Litter size	piglets	12	10.0	12	9.6	0.41	0.486
Litter growth	kg	12	99.7	12	100.5	5.08	0.912
Piglet weight deviation	kg	12	1.98	12	1.96	0.245	0.956
BW	kg	11	267.1	11	242.7	8.92	0.068
Relative weight loss	%	9	4.7	10	6.5	2.04	0.539
Backfat thickness	mm	11	14.0	11	13.9	1.25	0.967
Relative fat loss	%	11	15.7	10	15.4	6.35	0.971

Table 5
Number of socialised piglets and control piglets and their daily weight gain[1].

	Control piglets		Socialised piglets		SE	*P*-value
Time period[2]	n	Growth rate, g/day	n	Growth rate, g/day		
0 – 2 weeks	118	228	115	236	15.9	0.941
2 – 3 weeks	116	305	114	315	11.3	0.483
3 – 5 weeks	116	445	114	429	40.2	0.181
5 – 6 weeks	96	144	93	195	22.1	0.070

[1] Results are presented as least square means with pooled SE and significance of difference between treatments (*P*-value).
[2] Opening between pens at 2 weeks and weaning at 5 weeks of age.

before weaning to below 200 g/d after weaning), but this reduction in growth was lower for socialised piglets than for control piglets and socialised piglets tended to have higher growth rate than control piglets during the week after weaning ($P = 0.07$).

Skin lesions on piglets

The number of piglets with snout injuries was very low at all occasions (<3% at all inspections). Before opening between pens, one (to be) socialised piglet and four control piglets had 'few' injuries and one control piglet had 'several' injuries. After opening between pens (at two weeks of age), two socialised piglets and five control piglets had 'few' injuries and one control piglet (same as on the previous occasion) had 'several' injuries. At week three, two control piglets had 'few' injuries and one control piglet had 'several' injuries. At week four, one socialised piglet and two control piglets had 'few' injuries. The number of skin lesions was low, in average, 1.6 skin lesions per pig were found at each inspection, and out of these, 0.05 were 'severe'. Treatment did not affect the frequency of piglets with skin lesions recorded the day before opening between the farrowing pens. The day after opening, more socialised piglets than control piglets had skin lesions, 76.5 vs 41.7%, with about the same difference at head (55.7 vs 27.5%; $P < 0.001$), front (53.0 vs 23.3%; $P < 0.001$) and back (6.1 vs 0.8%; $P = 0.019$). Almost all of these skin lesions were 'mild' (99.0%). At the inspections at the age of 3 and 4 weeks, no difference in skin lesions was observed between treatments. At weaning, fewer socialised piglets than control piglets had lesions (25.0 vs 47.9%; $P = 0.001$) and the frequency of piglets with 'severe' skin lesions tended to be lower (0.0 vs 2.1%; $P = 0.09$). One week later, the occurrence of skin lesions did not differ between socialised and control piglets (24.2 vs 31.3%). There was no difference in skin lesions between female and entire male pigs at any of the inspections ($P > 0.3$).

Activity behaviour

The day before the opening between the farrowing pens, the proportion of piglets suckling at scan sampling did not differ significantly between the treatments (Table 6). The day after the opening, suckling was affected by treatment with a lower frequency of suckling for socialised piglets than for control piglets (7.7 vs 15.0%). At the piglet age of 4 weeks (3rd occasion), the proportion of suckling for socialised piglets had increased to around the same level as the control piglets (12.7 vs 13.6%). The proportion of piglets resting in the piglet corner or in the pen did not differ significantly between the treatments at any observation occasion before weaning. After weaning, more socialised piglets were resting outside the piglet corner, as compared to control piglets (25.9 vs 3.8%). The control piglets preferred resting in the piglet corner, as compared to the socialised piglets (72.9 vs 41.1%). The total proportion of resting piglets, either in the piglet corner or in the pen, did not differ significantly between treatments (67.0% for the socialised piglets vs 76.7% for the control piglets; $P = 0.90$). The frequency of piglets that were active was not significantly affected by treatment on any observation occasion. When analysed over time from the day before opening between the farrowing pens up until a piglet age of 4 weeks (with observation occasion as a fixed factor), socialised piglets became more active when they got older ($P = 0.050$), whereas no age-related effect was found for control piglets ($P = 0.38$).

Social behaviour

No sows were observed to perform aggressive behaviour, neither towards own nor towards other piglets. Treatment did not significantly affect the total number of aggressive and mounting interactions performed by piglets at any observation occasion (Table 7). Before weaning (1st, 2nd and 3rd occasion), the number of contact interactions did not differ between socialised and control piglets. After weaning (4th occasion), the socialised piglets showed more contact interactions than the control piglets (44.6 vs 22.9 interactions). At this time, when the socialised piglets were single-sex grouped, no difference in behaviour between groups of females and entire males could be found ($P = 0.42$). Irrespective of treatment, no age-related effect on the number of social interactions was found from the day before opening between the farrowing pens up until a piglet age of 4 weeks. Aggressive and mounting

Table 6
Percentage of piglets performing different scan sampling activity behaviours. Results are presented as least square means with pooled SE and significance of difference between treatments (*P*-value).

Activity behaviour[1]	Control piglets	Socialised piglets	SE	*P*-value
Before opening				
Suckling	12.5	16.0	0.16	0.405
Resting in piglet corner	63.5	57.0	0.60	0.560
Resting in pen	5.4	11.6	0.61	0.340
Active	18.6	15.4	0.17	0.465
Day after opening				
Suckling	15.0	7.7	0.12	0.046
Resting in piglet corner	57.7	69.1	0.24	0.132
Resting in pen	12.5	6.1	0.44	0.264
Active	14.7	17.1	0.23	0.646
At 4 weeks age				
Suckling	13.6	12.7	0.11	0.615
Resting in piglet corner	59.4	47.3	1.10	0.365
Resting in pen	6.1	10.4	0.38	0.448
Active	20.9	29.6	0.17	0.180
At weaning				
Resting in piglet corner	72.9	41.1	0.65	0.005
Resting in pen	3.8	25.9	0.38	0.002
Active	23.3	33.0	0.38	0.377

[1] See Table 1 for definitions of behaviour parameters used at the scan sampling.

Table 7
Total number of observed social interactions performed by 10 piglets per hour and proportion of interactions[1] directed towards litter mates. Results are presented as least square means with pooled SE and significance of difference between treatments (*P*-value).

Social interaction[2]	Control piglets	Socialised piglets	Interactions with litter mates[1],%	SE	*P*-value
Before opening					
Aggressive	19.2	24.9	-	0.19	0.343
Mounting	0.6	2.6	-	0.26	0.277
Contact	19.4	16.2	-	0.14	0.483
Day after opening					
Aggressive	19.4	24.8	67.1	0.68	0.634
Mounting	3.0	4.4	71.2	0.32	0.663
Contact	19.1	29.5	60.6	0.30	0.222
At 4 weeks age					
Aggressive	21.6	24.6	67.8	0.18	0.615
Mounting	4.9	6.1	62.5	0.15	0.647
Contact	23.1	26.2	59.0	0.26	0.674
At weaning					
Aggressive	4.1	6.0	57.1	0.23	0.545
Mounting	1.2	1.4	77.3	0.12	0.848
Contact	22.9	44.6	52.8	0.28	0.019

[1] Only for socialised piglets. Fisher's exact test was used to analyse differences in proportion of interactions directed toward litter mates and non-littermates in groups with socialised piglets. No significant differences in proportion were found ($P > 0.05$).
[2] See Table 2 for definitions of social interactions.

behaviours tended to be directed towards litter mates slightly more often than towards non-litter mates at all occasions in groups with socialised piglets (57–77% of interactions), but this difference was not significant (Table 7). After weaning, the total number of mounting interactions was very low. Among the socialised piglets, 45% of all mountings were performed by four piglets in two pens, and 80% of their interactions were performed with litter-mates.

No significant difference in the receiver's reaction on social interactions was seen between the two treatments on any observation occasion, but socialised piglets tended to show more 'escape' on the day after opening (2.7 vs 0.5% of total number of interactions within observation occasion, $P = 0.053$). Also when the treatments were compared within different social behaviours, no significant differences were found, except for the receiver's reaction on mounting at the observation occasion before opening ($P = 0.043$); in the treatment 'socialised', less piglets showed no reaction when exposed to mounting compared to the control piglets (27.7 vs 75.6%). When the piglets were exposed to an aggressive interaction, they reacted mostly with reciprocation at the three first observation occasions (78.8, 80.8 and 78.9%). After weaning (4th occasion), the piglet's two most common reactions to aggressive interactions were avoidance (49.4%) and reciprocation (35.0%). Sexual and other social interactions most often resulted in either no reaction (44.2% for mounting and 74.8% for contact) or avoidance (44.9% for mounting and 19.2% for contact) at all observation occasions. The reaction to social interactions did not differ between female and entire male piglets kept in single-sex groups after weaning ($P = 0.81$).

Nursing and cross-suckling

In total, 192 nursing events were observed. The nursing frequency decreased with time ($P = 0.030$), from 1.1 nursing per hour before opening between pens at two weeks of age (1st occasion) to 1.0 nursing the day after opening (2nd occasion) and to 0.9 at a piglet age of 4 weeks (3rd occasion). There was no difference in nursing frequency between treatments on any of the observation occasions. Ten sows never had any piglet missing at any of the

observed nursing events. At 18 nursing events, one piglet missed a nursing by its own sow and at three nursing events two piglets missed a nursing by their own sows. For socialised piglets with access to another pen, seven of the piglets missing a nursing were in the other pen and five were in the own pen when they missed a nursing. At the 1st observation occasion (before opening between pens), one or two piglets stayed in the piglet corner during one or two nursing and thus did not participate in suckling. On the 2nd occasion (after opening between pens), one control piglet and three socialised piglets (one located in the own pen and two in the adjacent pen) missed one nursing. On the 3rd occasion (piglet age 4 weeks), four control and ten socialised piglets did not participate in one or two nursings. Of the ten socialised piglets, five were in their own pen whereas five were in the adjacent pen during the missed nursing.

Cross-suckling among socialised piglets occurred in eight out of 192 nursing events, and five sows were objects of cross-suckling. One of these sows had a piglet from the adjacent pen at its udder at all observed nursing events on the 3rd occasion. For the other four sows, cross-suckling was only observed once. At five out of eight nursing events with cross-suckling, all the sow's own piglets were suckling at the same time as the additional piglets. Two cross-suckling piglets missed the simultaneous nursing of their own sow once. When udders were inspected in the fourth lactation week, all sows had enough number of teats in milk for their litter size. Of the control sows, three out of eleven sows had 1–2 surplus teats in milk (one sow did not allow a safe inspection) and the corresponding ratio for sows with socialised piglets was five out of twelve sows with 1–3 surplus teats in milk.

On the 1st observation occasion the day before opening between the farrowing pens, pair of sows nursed within two minutes of each other in 50.0% of the cases and with no significant difference between treatments (P = 0.75). The day after opening, synchronised nursing was numerically higher (although not significant), for sows with socialised piglets than for control sows (63.0 vs 43.8%; P = 0.22). At a piglet age of 4 weeks (3rd occasion), there was a tendency to higher frequency of nursing synchronisation for sows with socialised piglets, 64.7% compared to 37.0% for the control sows (P = 0.07).

Discussion

Performance, nursing and health of sows and piglets, and piglet behaviour before weaning

In a survey performed by Camerlink and Turner (2017), farmers expressed concerns about cross-suckling and missed suckling bouts if piglets were socialised. Based on previous studies of group-housed lactating sows (e.g. Maletínská and Špinka, 2001), we hypothesised that cross-suckling would occur. This hypothesis could not be rejected as some cross-suckling occurred, but cross-suckling was not frequent; seven of twelve sows had no observed cross-suckling and four sows had only one observed cross-suckling event. This was in accordance with results from groups of four sows with socialised piglets, where only 2.9% of the piglets performed any cross-suckling (Morgan et al., 2014). Total litter growth did not differ between treatments, which indicates that milk production was not affected. Accordingly, sows' loss of body reserves during lactation was the same for both treatments. The low number of sows (12 per treatment) must be kept in mind when interpreting these results.

Ledergerber et al. (2015) observed a changed behaviour of sows on the day when barriers between sows in crates were removed; that day the sows spent less time lying down and showed more restlessness than the days before and after. The stress caused by barrier removal seemed to be short, already the following day the behaviour was back to 'normal' (Ledergerber et al., 2015). Sows with socialised piglets studied by Hessel et al. (2006) also tended to be more restless when the barriers were removed. These authors separated between laying sternal and laying lateral (exposing the udder) and found that sows spent more time lying lateral (exposing the udder) the day after the barriers were removed. Cortisol analysis of sow saliva confirmed that sows were stressed on the day of barrier removal. The following day cortisol level decreased but was still higher than the other days. Also, control sows in the same farrowing stable showed higher cortisol levels on the day of barrier removal, but not the following day (Ledergerber et al., 2015). At the time when we designed the study, we had piglets in focus and sow activity was not recorded, but if we perform further studies on piglet socialisation we will include sow behaviour measurements.

We observed no difference in sows' health at the daily ocular health monitoring performed by the caretakers. Camerlink et al. (2018) studied sows in crates and found more teat injuries at weaning (four weeks) on sows with socialised piglets, but this what not the case for the twelve sows in our study, and also not found by van Kerschaver et al. (2021). Bite injuries on piglets' snouts could indicate severe competition for teats (van Nieuwamerongen et al., 2015) potentially leading to an increased risk for udder injuries, but the number of snout injuries was very low in this study and numerically lower for socialised piglets than for control piglets at all occasions. The lack of difference between treatments in sows' body condition at weaning (which is in accordance with van Kerschaver et al., 2021) and the low frequency of udder injuries together with the low frequency of cross suckling indicate that a higher number of piglets suckling or moving around at the udder competing for teats was not an issue in our study.

The nursing of pairs of sows with socialised piglets tended to be more synchronised (P = 0.07) when observed in week four, as compared to pairs of control sows in adjacent pens. The low number of sows in this study should be kept in mind, but synchronised nursing is often seen in group-housing systems and can be a strategy to avoid cross-suckling (Maletínská and Špinka, 2001). To study synchronised nursing, continuous recording of all sows with cameras during the whole lactation would have been preferable. The observers in our study got the impression that even if many piglets from both litters often were close to the udder and participated in the udder massage at the beginning of a nursing event, piglets from the adjacent pen went 'home' before milk let-down and these piglets often initiated a nursing event with their own sow. In future studies of cross-suckling and synchronisation, it would be good to record alien piglets at the udder not only during milk letdown but also during the previous massage phase. Seven socialised piglets occasionally missed a suckling in their home pen when they were in the adjacent pen. Nursing bouts were sometimes missed also by control piglets, but the percentage of piglets observed suckling during scan sampling was lower for socialised piglets than control piglets the day after opening between pens (7.7 vs 15.0, P < 0.05). Nursing frequency did not differ between treatments, and there was no unfavourable effect on piglet growth, i.e. no difference between treatments in piglet growth during the week after opening (or any period before weaning). Several other studies also showed that piglet growth before weaning was not affected by socialisation of piglets around two weeks of age (e.g. Hessel et al., 2006; Camerlink et al., 2018; van Kerschaver et al., 2021; Ji et al., 2021; Morgan et al., 2014).

Most previous studies were performed on sows in crates or in large family pens, and both these systems give piglets room to escape from threatening sows. In this study, the sow was kept louse in a rather small pen. Before opening between pens, the caretakers were concerned and they wondered if a sow would attack

alien piglets entering 'her' pen. Also, farmers in the survey performed by Camerlink and Turner (2017) expressed concerns about the aggression of sows towards piglets. However, no such aggressive behaviour was observed towards any of the piglets, neither during the observation occasions nor during the daily work in the pig stable. The observation time was limited and continuous recording with camera during the day of opening would have been a better method. The lack of observed aggressive behaviour of sows was, however, in accordance with the low number of injuries found on piglets at the individual inspection performed by a technician the day after opening.

The farmers in the survey performed by Camerlink and Turner (2017) expressed concerns about fights between piglets when they are socialised, and socialised piglets in our study and the study by Camerlink et al. (2018) had more skin lesions than control piglets the day after opening between pens. There were, however, almost no severe skin lesions in our study, and no observed differences in performed social behaviours this day (or at four weeks). Furthermore, the number of aggressive interactions did not differ between treatments.

Piglet behaviour and growth after weaning

The socialised piglets had a higher growth rate than the control piglets during the week after weaning, which indicates that they were less disturbed by weaning. When comparing our results with other studies, it should be remembered that in this study, no piglets were mixed with unknown piglets at weaning. Instead, groups of female and male siblings (control) were compared to sex-sorted groups of socialised piglets. The sow was moved at weaning, not the piglets. Thus, the weaning was a relatively 'gentle' process for the piglets, compared to routines often used in practice. On the other hand, the males were not castrated and entire males usually perform more aggressive behaviour and more mounting than females (von Borell et al., 2020) and castrated males (Rydhmer et al., 2010). Furthermore, both socialised and control piglets experienced loss of group members since the group size after weaning was eight piglets. When pigs are moved from a group the remaining pigs need to establish a new social rank order which can provoke aggressive behaviour. Fàbrega et al. (2013) found that pigs socialised at two weeks of age later, during the finishing phase, had less skin lesions after split marketing than pigs that had been raised in their litters and randomly mixed when entering the growing/finishing unit. Their interpretation was that socialised pigs have a higher ability to establish a new social rank order.

Environmental changes such as losing the mother and some group members, and being kept in one pen (instead of two pens) with piglets from another litter (although well-known), could have provoked aggressive or sexual behaviour among the entire males, but that did not happen. In general, entire male pigs perform more aggressive behaviour and mountings than female pigs, due to sexual steroids, but most studies of aggressive and sexual behaviour as well as puberty of entire male pigs are performed during the finishing phase (reviewed by von Borell et al., 2020). Clouard et al. (2022) studied litters with entire males and females at three and six weeks of age, which was before weaning. The piglets performed more agonstic behaviour, nudging and mounting at six weeks than at three weeks of age. Even though six weeks of age is several months before puberty, the entire male piglets performed more of these behaviours than females. In our study, socialised entire male piglets showed as little aggressive and mounting behaviour after weaning as socialised females kept in sex-sorted pens and as control piglets kept with litter mates with four piglets of each sex. Due to environmental differences before and after weaning, studies should be compared with care. Nevertheless, several studies show that socialised piglets are better prepared for life after weaning (e.g. Hessel et al., 2006; Morgan et al., 2014; Camerlink et al., 2018). The socialised piglets in our study had less skin lesions after weaning than control piglets, and they showed more non-aggressive interactions ('contact'). Although pigs are social animals, a high frequency of social contact, even if it is non-aggressive, can probably be stressful – especially if these interactions hinder pigs from resting (Rydhmer et al., 2010). There was, however, no significant difference in percentage of active piglets between socialised piglets and control piglets in our study (Table 6).

Future implementation

The study reported here and previously (Rydhmer et al., 2013) is one of several studies showing the benefit of socialising piglets. Improving piglets' social skills can lead to better welfare for growing pigs. We conclude that these improvements come without trade-offs for the sows. Socialising piglets is, however, not yet common practice in conventional production systems in-doors (Peden et al., 2018). Some explanations are given by Camerlink and Turner (2017): farmers express concerns regarded the practical management of piglets and sows, aggression of the sow towards piglets and reduced growth of piglets. Such problems were not confirmed by our results. In practice, Peden et al. (2021) estimated negligible costs for the initial modification of walls and the extra work with removing barriers between pens for every batch, in systems with crated sows. With louse-housed sows in individual farrowing pens, there is an initial cost when small doors are installed in the pen walls but thereafter the only extra work is to open (and later close), these doors once for each batch. We encourage farmers to install doors between pens in some farrowing stables and test piglet socialising as a new routine for a year. If a farmer is not satisfied with the results of this test, the doors can simply be permanently closed. We do, however, predict that sows will be unaffected and pigs' aggressive behaviour will decrease, leading to a better animal welfare overall.

Conclusions

We conclude that socialising piglets of two adjacent pens with sows that are not kept in crates has no unfavourable effect on sow health, nursing or piglet growth. We also conclude that socialised piglets are not injured by sows and that socialising piglets does not expose them for an increased risk of being severely attacked or mounted by other piglets. Based on a tendency of higher growth rate the week after weaning and lower amount of skin lesions of socialised piglets, we conclude that the socialised piglets withstand weaning better than control piglets even when compared to control piglets that are not mixed with foreign piglets at weaning. Thus, socialising entire male piglets (and their sisters) improve piglet welfare without negative effects on their sows.

Ethics approval

The study was approved by the local Ethics Committee on Animal Research, Uppsala, Sweden (Dnr C214/10, 2010-11-26), ensuring compliance with EC Directive 86/609/EEC for animal experiments.

Data and model availability statement

None of the data were deposited in an official repository. Data are available on request from the first author.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) did not use any AI and AI-assisted technologies.

Author ORCIDs

Lotta Rydhmer: https://orcid.org/0000-0002-2167-5475.

CRediT authorship contribution statement

L. Rydhmer: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **K. Andersson:** Writing – original draft, Formal analysis, Data curation.

Declaration of interest

None.

Acknowledgements

We thank MSc student Lisa Eriksson who performed behavioural observations, and all staff at the Swedish Livestock Research Centre Lövsta who took good care of the pigs. Our former co-worker Kerstin Lundström inspired us to study entire male pigs, and we remember her with appreciation. The study was performed within a European project called Q-PORKCHAINS.

Financial support statement

This work was supported by the European Union under the 6th European community framework programme for research, technological development and demonstration activities (grant number Q-PORKCHAINS FOOD-CT-2007-036245).

References

Allwin, B., Gokarn, N.S., Vedamanickam, S., Gopal, S., 2016. The wild pig (Sus scrofa) behavior- a retrospective study. Journal of Dairy Veterinary & Animal Research 3, 115–125.

Bünger, B., Zacharias, B., Schrade, H., 2014. Behavioural differences between entire boars, castrated males, and gilts kept in single or mixed sex groups under different housing and feeding conditions during fattening. Züchtungskunde 86, 358–373.

Camerlink, I., Turner, S., 2017. Farmers' perception of aggression between growing pigs. Applied Animal Behaviour Science 19, 42–47.

Camerlink, I., Farish, M., D'Eath, R.B., Arnott, G., Turner, S.P., 2018. Long term benefits on social behaviour after early life socialization of piglets. Animals 8, 192.

Clouard, C., Resmond, R., Prunier, A., Talle, C., Merlot, E., 2022. Exploration of early social behaviors and social styles in relation to individual characteristics in suckling piglets. Scientific Reports 12, 2318.

Fàbrega, E., Puigvert, X., Soler, J., Tibau, J., Dalmau, A., 2013. Effect of on farm mixing and slaughter strategy on behaviour, welfare and productivity in duroc finished entire male pigs. Applied Animal Behaviour Science 143, 31–39.

Fredriksen, B., Lium, B.M., Marka, C.H., Mosveen, B., Nafstad, O., 2008. Entire male pigs in farrow-to-finish pens - effects on animal welfare. Applied Animal Behaviour Science 110, 258–268.

Friebel, B.A., Jodice, P.G.R., 2009. Home range and habitat use of feral hogs in Congaree National Park, South Carolina. Human-Wildlife Conflicts 3, 49–63.

Hessel, E., Reiners, K., Weghe, H., 2006. Socializing piglets before weaning: Effects on behavior of lactating sows, pre- and postweaning behavior, and performance of piglets. Journal of Animal Science 84, 2847–2855.

Jensen, P., Redbo, I., 1987. Behavior during nest leaving in free-ranging domestic pigs. Applied Animal Behaviour Science 18, 355–362.

Ji, W., Bi, Y., Cheng, Z., Liu, R., Zhang, X., Shu, Y., Li, X., Bao, J., Liu, H., 2021. Impact of early socialization environment on social behavior, physiology and growth performance of weaned piglets. Applied Animal Behaviour Science 238, 105314.

Ledergerber, K., Bennett, B., Diefenbacher, N., Shilling, C., Whitaker, B.D., 2015. The effects of socializing and environmental enrichments on sow and piglet behavior and performance. The Ohio Journal of Science 115, 40–47.

Maleťínská, J., Špinka, M., 2001. Cross-suckling and nursing synchronisation in group housed lactating sows. Applied Animal Behaviour Science 75, 17–32.

Morgan, T., Pluske, J., Miller, D., Collins, T., Barnes, A.L., Wemelsfelder, F., Fleming, P. A., 2014. Socialising piglets in lactation positively affects their post-weaning behavior. Applied Animal Behaviour Science 158, 23–33.

Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Canali, E., Drewe, J.A., Garin-Bastuji, B., Gonzales Rojas, J.L., Gortázar Schmidt, C., Herskin, M., Michel, V., Miranda Chueca, M.A., Padalino, B., Roberts, H.C., Stahl, K., Velarde, A., Viltrop, A., Winckler, C., Edwards, S., Ivanova, S., Leeb, C., Wechsler, B., Fabris, C., Lima, E., Mosbach-Schulz, O., Van der Stede, Y., Vitali, M., Spoolder, H., 2022. Scientific opinion on the welfare of pigs on farm. EFSA Journal 20, 7421.

Noblet, J., Etienne, M., 1989. Estimation of sow milk nutrient output. Journal of Animal Science 67, 3352–3359.

Peden, R.S.E., Turner, S.P., Boyle, L.A., Camerlink, I., 2018. The translation of animal welfare research into practice: the case of mixing aggression between pigs. Applied Animal Behaviour Science 204, 1–9.

Peden, R.S.E., Turner, S.P., Camerlink, I., Akaichi, F., 2021. An estimation of the financial consequences of reducing pig aggression. PLoS ONE 16, e0250556.

Rydhmer, L., Lundström, K., Andersson, K., 2010. Immunocastration reduces aggressive and sexual behaviour in male pigs. Animal 4, 965–972.

Rydhmer, L., Hansson, M., Lundström, K., Brunius, C., Andersson, K., 2013. Welfare of entire male pigs is improved by socialising piglets and keeping intact groups until slaughter. Animal 7, 1532–1541.

Salazar, L.C., Ko, H.-L., Yang, C.-H., Llonch, L., Manteca, X., Camerlink, I., Llonch, P., 2018. Early socialisation as a strategy to increase piglets' social skills in intensive farming conditions. Applied Animal Behaviour Science 206, 25–31.

Van Kerschaver, C., Vandaele, M., Degroote, J., Van Tichelen, K., Fremaut, D., Van Ginneken, C., Michiels, J., 2021. Effect of starting time of co-mingling non-littermates during lactation on performance and skin lesions of sows and piglets. Livestock Science 250, 104563.

Van Nieuwamerongen, S.E., Soede, N.M., Van der Peet-Schwering, C.M.C., Kemp, B., Bolhuis, J.E., 2015. Development of piglets raised in a new multi-litter housing system vs. conventional single-litter housing until 9 weeks of age. Journal of Animal Science 93, 5442–5454.

Von Borell, E., Bonneau, M., Holinger, M., Prunier, A., Stefanski, V., Zöls, S., Weiler, U., 2020. Welfare aspects of raising entire male pigs and immunocastrates. Animals 10, 2140.