Title: Evaluation of the effect of group size and structure on welfare of gestating sows in pens with electronic sow feeders (ESFs) – **NPB #03-098**

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Abstract: The welfare of 400 pregnant sows (Yorkshire X Landrace crossbreds, 146 – 294 kg body weight and parities of 0-7) housed in dynamic, two-time mixing and static groups of different sizes in pens with ESF was evaluated in terms of salivary cortisol concentrations, injuries and behavior along with their production performance and longevity to study the effect of group size and structure on sow welfare. The economic implications of changing group sizes and structure were also studied. The study was conducted at SROC, Waseca, of the University of Minnesota. A fortnightly weaning system was followed in the unit and it consisted of 20-30 animals per weaning batch allotted to pens with ESF. Four weaning batches were introduced at bi-weekly intervals to a large pen with two ESFs and 6 water bowels formed by combining 2 adjacent pens to form the dynamic grouping treatment. The two-time mixing treatment was formed by adding 2 weaning batches at bi-weekly interval and 2 such pens were maintained. Static group of single weaning batch was accommodated in one half of a pen and 4 such batches were maintained. Behavior data using video camera and time-lapse VCR, and saliva samples were collected from 15 randomly identified focal sows from each batch newly added batch. Injury levels of all sows were assessed. Saliva collection and injury level assessment were performed the day before, day after and 2 weeks after introduction. Behavior data were collected on the day, day after and 2 weeks after introduction. The body weight and backfat thickness of all sows were assessed on the day of weaning and at 109 days of gestation. Video tapes were analyzed for agonistic non-agonistic, postural and stereotypic behaviors using the software “Observer” and saliva samples were analyzed for cortisol concentration using RIA. Productivity parameters and longevity were assessed based on the PigChamp records of the unit. The initial investment, loss if any due the modification and extra labor requirement in the grouping treatments calculated. Labor requirement was calculated using the time allotted for routine operations in each grouping treatment during the study period. The data were analyzed using descriptive statistics, repeated measures of ANOVA, spearman rank correlations, ANOVA and 2-sample proportion tests.

The salivary cortisol concentrations of sows housed in the three grouping treatments were similar. The dynamic group had the highest ($P<0.05$) TIS. The cortisol concentration and TIS were higher ($P<0.05$) at day after mixing compared with those at 2 weeks after mixing. The TIS was significantly ($P<0.05$) different among the treatments at 2 weeks after mixing with the dynamic group treatment having higher ($P<0.05$) score than the static. The number of queuing was higher ($P<0.05$) in the two-time mixing group. The proportion of time spent lying and standing were lower ($P<0.01$) in the dynamic group compared to the other two treatments. The average number of non-agonistic social interaction was lower ($P<0.05$) in the dynamic group and the proportion of time spent walking was less ($P<0.01$) in the dynamic group. Grouping treatment had no effect on number of total aggressions and proportion of time spent on queuing, stereotypies, sitting and non-social physical interactions / exploration. The proportion of time spent queuing was lesser ($P<0.01$) at mixing day compared to that 2 weeks later among the grouping treatments. The proportion of time spent walking was less ($P<0.001$) on the day following mixing. The proportions of time spent on stereotypies and standing were the highest ($P<0.001$) at 2 weeks post-mixing. The numbers of total aggression, queuing and non-agonistic social interactions and proportion of time spent on non-social physical interactions, sitting and lying were similar at different time points of observation. The proportions of time spent lying was higher ($P<0.05$) in the static group on the day following mixing compared to the dynamic group. The proportion of time spent walking was less ($P<0.05$) in the dynamic group on the day of mixing and two weeks later. The grouping treatments at different time points of observations were similar in proportions of time spent standing, sitting, stereotypic behavior, non-social physical interactions and queuing. The numbers of total aggression, queuing and non-agonistic social interactions did not vary with the time point of observation among the grouping treatments. Cortisol concentration and TIS were positively correlated ($P<0.05$) in dynamic and two-time mixing groups. Total aggression was positively correlated ($P<0.05$) with number of queuing in the all the systems. The total aggression was positively correlated ($P<0.05$) with queue duration in all the treatments. The farrowing performance and longevity of sows in the grouping treatments were similar. The time required for routine management was higher in the dynamic group and there was little difference in cost of penning or space used among the treatments. The higher TIS and lower number of non-agonistic social interactions observed in this study indicated that the welfare of sows in the dynamic group was compromised compared to the other grouping treatments. Aggression at mixing and competition for feeder entry appeared to be the major threats to the welfare of sows in group systems with ESF, regardless of the difference in group size and structure. Pen and feeder designs require modifications to reduce aggression at mixing and hunger in order to improve the welfare of sows in pens with ESF.

Introduction: Many of the welfare challenges pertaining to the gestating sows in terms of injuries and disease are related to the housing system utilized by a producer. The lack of space within stalls relative to the size of the sow has led to wide criticism of the stall system despite its advantages. The main alternative that has existed to a stall system is group housing of pregnant sows. Group housing however, also has potential detrimental affects of the welfare of the individual sow, aggression between sows at the time of mixing, and competition for feed in a feed-restricted environment. It may be possible to maintain static groups when the scale of operation is really small. However, in large scale intensive systems sows may have to be added and removed at frequent intervals to make efficient use of the facilities. Many farms follow a less intensive type of grouping, wherein sows are added to the existing group two or three times. Frequent addition of sows to the system results in aggression. Intervention such as the electronic sow feeder (ESF) in group housed systems has enabled the producers to ensure control over individual feed intake. Although group housing with ESF improves animal welfare as compared with confinement in terms of freedom of movement and space availability, it allows only one sow to eat at a time, resulting in a highly competitive environment and possibly in injuries. There are reports indicating higher levels of aggression and injuries in pigs housed in groups with ESF (Broom *et al*., 1995; Anil *et al.,* 2004). Attempts to reduce competition for feed by providing more fiber diet may have the disadvantage of difficulties in manure handling and costs of diets.

Group size and structure (dynamic/ static) are factors that influence the aggressive behavior of group-housed sows (den Hartog *et al.* 1993). The level of aggression is less in static groups (Gonyou, 2002) after the initial establishment of social hierarchy. The introduction of new sows at frequent intervals (dynamic groups) results in aggressive interactions to establish a new social hierarchy (Simmins, 1993; Lambert *et al*., 1986). Although large groups allow animals to avoid and /or escape from aggressive pigs (Gonyou, 2002) and allow sub-group formation (Gonyou, 2001), the optimum group size for pregnant sows is yet to be determined. Small static groups are not practical under farm conditions. At the same time, large static groups are not economical as such groups will hinder the efficient use of the facilities. The present research proposed to have dynamic and static groups of different sizes (approximately 25-sows in static group, 50-sows in two-time mixing group and 100-sows in dynamic group) to study the effect of group size and structure on sow welfare in terms of salivary cortisol concentrations, injuries and behavior among sows housed in pens with ESF along with their production performance and longevity. It was also proposed to analyze the economic implications of changing group sizes and structure.

Specific goals:

1. To evaluate the welfare indicators of pregnant sows housed in ESF pens under different group sizes and structures.
2. To assess the economic implications of changing the group sizes and structures.

Materials and methods:

General

The study was conducted at The University of Minnesota, Southern Research and Outreach Center at Waseca. The research unit is an 800-sow (Yorkshire X Landrace crossbreds) breed to wean facility. This facility had 6 pens of 12.75 x 6.75 m size, with a central walk-through ESF (Osborne Industries TEAM electronic sow feeder, Kansas, USA, manufactured in 2001) in each pen and conventional gestation stalls. Each pen had fully slatted flooring and 3 watering bowls positioned at the partition walls between pens. Each pen was sufficient to house up to 60 sows.

Diets, Housing and Husbandry

Feed was dispensed with water in the ESF, allowing the sows to stay to consume feed without having to leave the ESF to drink water. The sow-identification in the ESF was at the point of feed delivery. A sow was identified only when she put her head into the feeding bowl inside the ESF. As there was no sow identification at the gate of the ESF, a sow was permitted entry into the ESF any number of times even after receiving her daily allowance. The entry door of the ESF was electronically controlled and it remained closed for 30 seconds if a sow that had already consumed her daily allotment of feed entered the ESF, after which time the door automatically opened to admit another sow. Sows were fed 2.2–3.0 kg of feed daily (CP content 15%), based on body weight and backfat at weaning. The sows were fed an average 2.2 kg/ day from breeding to day 90 of gestation. The feed allowance was increased to 2.4 kg from days 91 to 97 and increased again to 2.6 kg from day 98 until day 109 when they were moved into the farrowing stalls. The sows were then offered 3 kg feed per day until farrowing. The feed was offered to a sow in the ESF in 100 g allotments every 35 seconds with 25 ml of water at each feed delivery.

All sows were weaned at 17-22 days of lactation and were housed in gestation stalls for the first 10 days before moving to either the gestation stall or pens with ESF. Sows of different body weights (146 – 294 kg) and parities (0-7) were selected for the study according to the routine allocation system of the farm. The dynamic group of sows was housed in a pen of 12.75 x 13.5 m (formed by combining two adjacent pens) with 2 ESF and 6 watering bowls. A fortnightly weaning system was followed in the unit and it consisted of 20-30 animals per weaning batch allotted to pens with ESF.

For the establishment of dynamic group, 2 adjacent pens of 50 sows each were combined one month before the start of the experiment. First batch of experimental sows was added to this large combined pen with two ESF's and 6 water bowels 5 days after breeding, when another batch of sows in advanced gestation from the combined pen was moved to the farrowing stall. The next batch was introduced 14 days later upon removal of another batch of sows in advance gestation and this was continued until the fourth batch of sows was added. The 4 batches remained together until the first batch of experimental sows was moved to farrowing stall and then another batch of new sows was added to keep the group size constant. This was continued until all the 4 batches were removed from the pen. For the establishment of the two-time mixing group, first batch of weaned sows was mixed in pens 5 days after breeding and the second batch was mixed 14 days later. Another two-time mixing group was also formed and maintained similarly. A pen was partitioned into two (from corner to corner) and one batch of static group of sows was accommodated in one half. These sows were fed from a single ESF by regulating the feeding time. Another three batches of sows each were accommodated in a similar manner. Dynamic system consisted of 98 (batches of 25, 24, 27 and 22), two-time mixing consisted of 109 (batches of 22, 28, 29 and 30) and static group consisted of 103 (batches of 31, 23, 25 and 24) sows.

Data were collected from the sows in newly introduced batches only. For saliva collection and behavior observation 15 sows from each batch were identified randomly as focal sows. However, some of these sows were returned and only less saliva could be obtained for some other sows. The data from such sows were not included in the analysis. Injury scores were collected from all sows.

Measurements:

***Stress level*:**

<u>Salivary cortisol</u>: Saliva samples were collected from focal sows one day before moving to pens, day after mixing and 2 weeks after mixing. Saliva samples were collected using

a salivette with cotton wool swab (SARSTEDT, Aktiengesellschaft and Co, Numbrecht, Germany). Sows were allowed to chew the cotton wool swab clipped to a flexible thin metal rod until the swab was thoroughly moistened. Care was taken to keep the sows minimally disturbed to avoid activity during the process of saliva collection and the saliva samples were collected between 10-11am on all collection days. Approximately 3 minutes were needed to collect saliva from a sow. The Salivette with moistened cotton swabs were centrifuged at 2000 rpm for five minutes to extract the saliva and kept frozen at –20 ^{0}C until radioimmunoassay. Approximately 0.5 ml saliva was obtained from each swab. The solid phase cortisol radioimmunoassy kit, (Coat-A-Count TKCO, Diagnostic Products Corporation, Los Angels, U.S.A) was modified to measure cortisol concentrations in saliva. Phosphate buffered solution (0.01M and 7.2pH) was used to dilute the supplied human serum based calibrators to final cortisol concentrations of 0.000 (maximum binding or B0), 0.3125, 0.625, 1.25, 2.5, 5, 10, 20, and 40 ng/ ml. Saliva samples and calibrators were analyzed in duplicate aliquots of 200µl; after adding ^{125}I cortisol, tubes were mixed and incubated for 45 minutes at 37^{o}C. Following incubation, unbound ^{125}I cortisol was aspirated and remaining radioactivity was counted using a gamma counter (Packard instrument company). The recovery rate of calibrator cortisol added to porcine saliva was determined by adding calibrator solutions to saliva containing both relatively high and low concentrations of endogenous cortisol. The recovery percentage of cortisol from the saliva was 102%. The intra-assay coefficient of variation calculated from duplicate low, medium and high cortisol saliva pools was 5.9%. Different amounts of calibrators added to the saliva samples gave a slope similar to that of the calibrator added to the buffer solution. The minimal detectable sensitivity (concentration at 93% of the maximum binding) of the assay was 0.31ng/ml

Injury scores: Injuries of all sows were scored after saliva collection from focal sows one day before moving to pens, day after mixing and 2 weeks after mixing. Injuries were assessed according to a scoring pattern reported (Anil *et al*., 2003). Injuries on various body parts such as ear (right and left), snout, face, forehead, shoulder (right and left sides), forelimb (right and left), neck (right and left sides), thorax (right and left sides), flank (right and left sides), top of the back (dorsum), udder, croup-hind quarters (right and left sides), hind limb (right and left), tail and vulva were recorded. If the depth of a wound was > 0.5 cm, it was considered a deep wound. A score of zero was given for no injury, 1 for mild injury (< 5 superficial wounds), 2 for obvious injury (5 to 10 superficial wounds, $\leq$ 3 deep wounds, or both), and 3 for severe injury (> 10 superficial wounds, > 3 deep wounds, or both). Total injury score (TIS) was calculated by adding injury scores for individual sites. The same individual did scoring of all injuries.

Behavior: For behavior study, focal sows from newly introduced batch were randomly selected and the behavior of these sows was recorded using a time-lapse video recorder for 24 hours at 30H speed (12 fields/seconds). The cameras were fixed on the ceiling of the pen in such a way to view an area including the entry and exit of the ESF in the field of vision. The field of vision was similar in all the grouping systems. The frequency and duration of behaviors for the first 15 minutes of every hour for the 24 h period were analyzed from the videotape using a software ('The Observer', version 4.1. Noldus Information Technology Inc, Leesburg, USA). For the dynamic group, the behavior was recorded on the day of introduction, and 24 h after the introduction and 2 weeks after the introduction (before the introduction of the next batch) for each batch. For the two-time mixing group, the behavior of focal sows out of the first batch of sows was recorded on the day of introduction and 24 h after the introduction and 24 h before (at second week) the introduction of the subsequent group. In the second batch of sows in the two-time mixing group, behavior of focal sows was recorded on the day of introduction 24 h after their introduction and 2 weeks later. In the static group, behavior of focal sows was recorded on the day of introduction, 24 h after their introduction and 2 weeks later. Agonistic interactions and stereotypies, non-agonistic social interactions with pen mates and non-social physical interactions as well as time spent lying, standing, sitting and walking among sows were recorded continuously for 24 h (Table 1).

Table 1. Behavioral ethogram for sows housed in pens with ESF following the behavioral definitions from Jensen (1980), Jensen *et al*., (1995) and Morrison *et al*., (2003).

Behavior	Definition
Agonistic	Performed and received such as parallel pressing (two pigs standing side-by-side in the same direction, pressing against each other's shoulder, with one throwing its head against the head or the neck of the other pig), inverse parallel pressing (two pigs standing side-by-side in opposite directions, pressing against each other's shoulder/croup), head-to-head knock (a rapid thrust upward or sideways with the head or snout against the neck, head or ears of another pig), levering (the pig puts its snout under the body of another pig from behind or from the side and lifts the other pig up into the air) and biting on any part of the body. The agonistic behaviors such as threat (without actual physical contact performed with head) performed or received were also recorded.
Postures	Standing (the pig is upright on all four legs), lying (the pig is recumbent on its belly, either sternal or lateral recumbency) and sitting.
Queuing	Waiting in front of the ESF entrance for an opportunity to enter the feeder. The duration of waiting by each sow till entry or leaving the attempt was taken as the duration of queuing and presented as proportion of time spent queuing and the number of times a sow queues was treated as the queue number.
Non-social physical interactions	Nosing the concrete floor (counted only if the snout of a pig had physical contact with the surface or it approached within 5 cm of the surface).
Social tactile interactions	Nose-to-body and nose-to-nose interactions performed and received.
Stereotypy	Behavioral patterns performed repetitively in a fixed order and without any obvious function such as repetitive vacuum chewing and pen fixture biting/licking were considered

Sow condition: All sows were weighed and backfat measurements were taken on the day of allocation into the treatment (at weaning day) and at 109 days of gestation. The backfat was measured at the last rib using a Lean-Meater® ultrasound unit (Renco Corporation, Minneapolis, MN).

Productivity parameters: Productivity parameters for the study period were assessed based on records. Sow (body weight and backfat changes during gestation, wean to service interval and pregnancy rate by d 45 of gestation) and litter (total pigs born, total pigs born alive, total pigs weaned, pig birth and weaning weights) performances were determined.

Diseases and mortality: Incidences and causes of diseases and mortality during the study period were assessed based on records.

Economics: In terms of initial investment, loss if any due the modification and extra labor requirement in the system were calculated. Labor requirement was calculated using the time allotted for routine operations in each grouping treatment during the gestation period.

Statistical analysis: Each weaning batch was treated as replicate and four replicates per grouping treatment were conducted. The weaning batch was considered as experimental unit. Mean and SE, median and range were used to describe the data collected. All the agonistic interactions received or performed were added together and expressed as aggressions performed or received for behavior analysis. The proportion of time spent on a specific behavior was expressed as percentage of observation time and the number of occurrences in observation time was expressed as frequency of behavior. Repeated measures of ANOVA (Proc Mixed) with data collection time as 'within group factor' and treatment (dynamic, 2-time mixing and static grouping treatments) as 'between group factor' were performed for cortisol concentrations, injury levels and behavior. In all the analyses the interactions between time and treatments were also included. Means were compared using Tukeys pairwise comparison with SAS-Probability difference option (SAS-PDIFF). Spearman rank correlations were used to assess the associations of cortisol concentrations with TIS and total aggressions and the associations of total aggressions with number and duration of queuing and TIS. ANOVA (Proc ANOVA) and 2-sample proportion tests were performed for comparing the production performance. All the analyses were performed using SAS (version 9.1, 2003). A *P* value of $\leq$ 0.05 was considered significant for all comparisons.

Results:

Stress level and injury scores

Table 2 shows the effect of grouping treatments and time of observation on the salivary cortisol and injury levels of sows housed in dynamic, 2-time mixing and static groups. The change over time in salivary cortisol concentration and TIS in the three grouping treatments are shown in Figure 1 and Figure 2. The salivary cortisol levels of sows housed in the three grouping treatments were similar whereas TIS showed a significant (P<0.05) difference among the treatments with the highest score in dynamic groups (Table 1). Both the cortisol concentration and TIS were significantly (P<0.05) higher at day after mixing compared with those at 2 weeks after mixing (Table 2).

Table 2. Mean and SE of salivary cortisol concentration (ng/ml) and Total injury scores among sows housed in dynamic, 2-time mixing and static groups at day after mixing and 2 weeks after mixing

Measures	Effect of housing treatments			P	Effect of time		P
	Dynamic group	Two-time mixing	Static		Day after mixing	2 weeks after mixing	
Cortisol (ng/ml)	4.189 $\pm$ 0.506	5.470 $\pm$ 0.547	5.255 $\pm$ 0.791	NS	6.201 $\pm$ 0.468^{a}	3.741 $\pm$ 0.252^{b}	0.0003
Total injury scores	24.88 $\pm$ 0.807^{a}	19.184 $\pm$ 0.708^{b}	19.093 $\pm$ 1.435^{b}	0.01	22.602 $\pm$ 0.966^{a}	19.502 $\pm$ 1.1504^{b}	0.0005

NS –Statistically not significant. ^{a,b}Within each row, values with different superscripts differ significantly in their means ($P<0.05$).

The salivary cortisol levels of sows housed in the 3 grouping treatments were similar at day after mixing and 2 weeks after mixing (Figure 1). Although the TIS were similar at day after mixing among the treatments, the TIS was ($P<0.05$) different among the treatments at 2 weeks after mixing (Figure 2) with the dynamic groups having higher ($P<0.05$) score than the static groups. The cortisol concentrations (0.936 $\pm$ 0.243, 1.698 $\pm$ 0.27 and 1.206 $\pm$ 0.389 in dynamic, two-time mixing and static grouping treatments respectively) and TIS (6.253 $\pm$ 0.163, 6.417 $\pm$ 0.405 and 5.056 $\pm$ 0.391 in dynamic, two-time mixing and static grouping treatments respectively) at pre-introduction stage in all the grouping treatments were lower ($P<0.05$) than those on day after mixing and 2 weeks after mixing.

Figure 1: Cortisol concentration (ng/ml) among sows (Mean and SE) in housing systems at observation time points

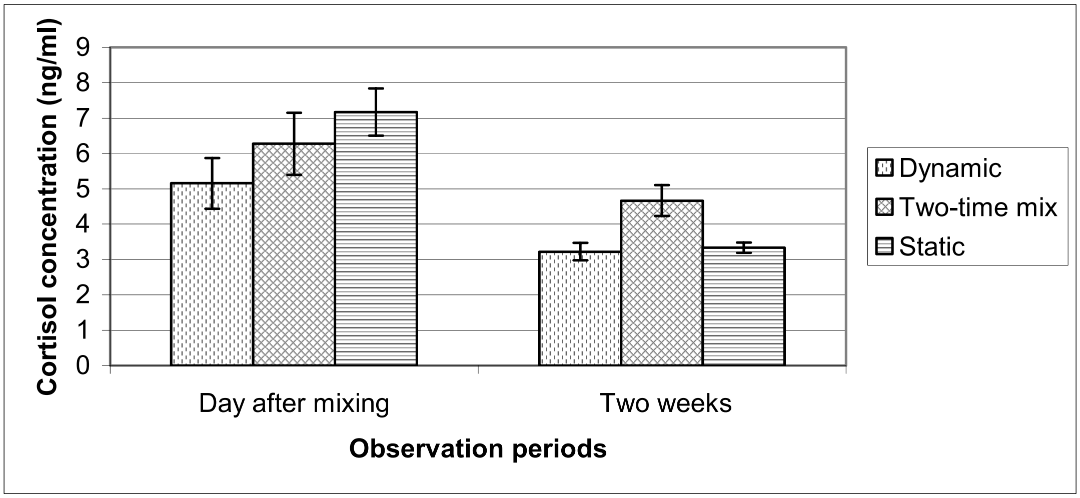
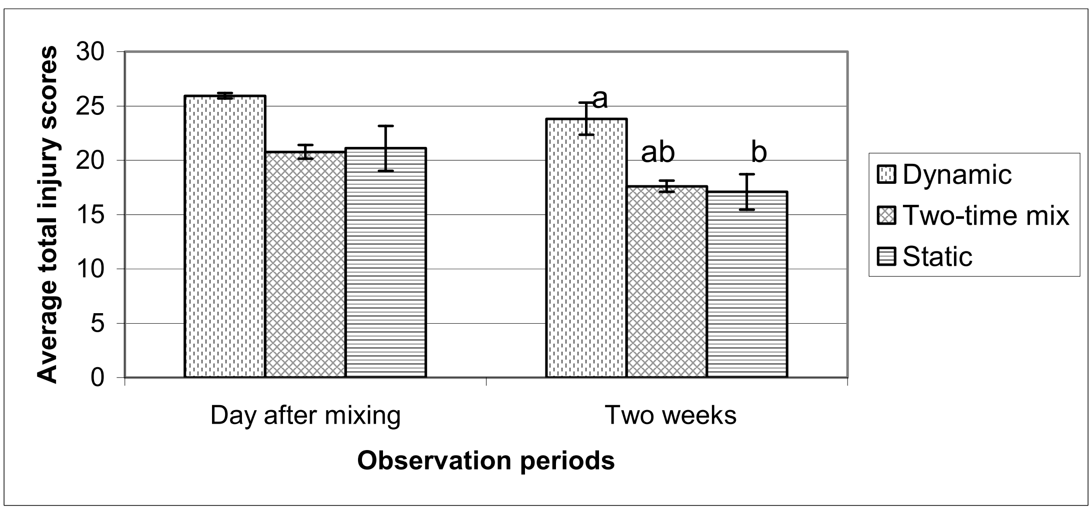


Figure 2: Total injury scores among sows (Mean and SE) in housing systems at observation time points



Behavior

The effect of grouping treatments and of time points of observation on sow behaviors is presented in Table 3.

The number of queuing was ($P<0.05$) higher in the two-time mixing group (Table 3). The proportion of time spent lying and standing were lower ($P<0.01$) in the dynamic group compared to static and two-time mixing groups. The average number of non-agonistic social interaction was lower ($P<0.05$) in the dynamic group compared to the static group although it was not different from that in the two-time mixing group. The proportion of time spent on walking was less (P<0.01) in the dynamic group compared to the two-time mixing group and it was similar to that in the static group. Grouping treatment had no effect on number of total aggressions and proportion of time spent on queuing, stereotypies, sitting and non-social physical interactions / exploration, (Table 3).

The proportion of time spent queuing was less (P<0.01) at mixing day compared to that 2 weeks later (Table 3). The proportion of time spent walking was less (P<0.001) on the day following mixing. The proportions of time spent on stereotypies and standing were the highest (P<0.001) at 2 weeks post-mixing. The numbers of total aggression, queuing and non-agonistic social interactions and proportion of time spent on non-social physical interactions, sitting and lying were similar at different time points (mixing day, day after mixing and 2 weeks after mixing) of observation (Table 3).

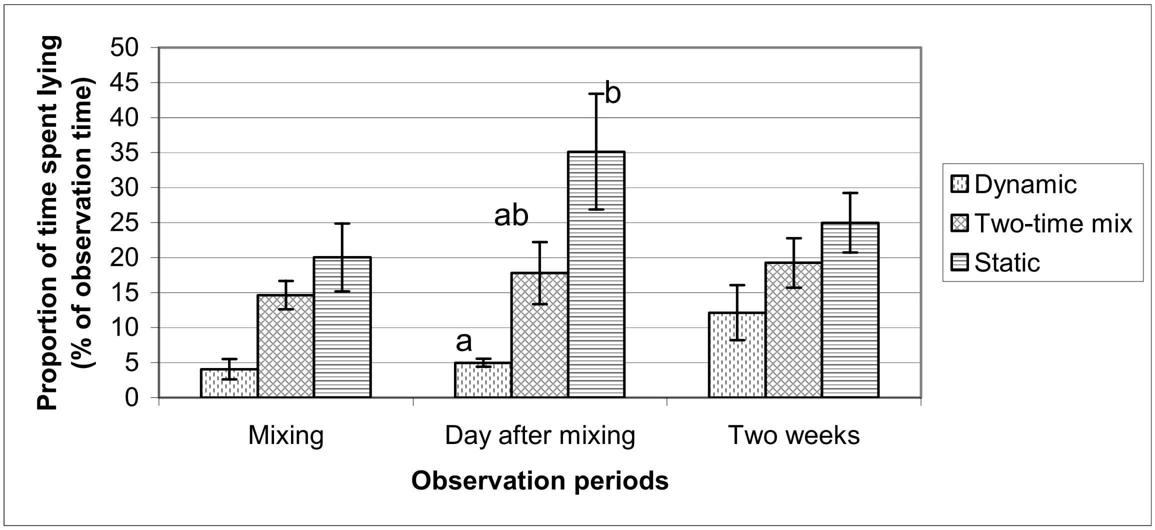
The change over time in the proportion of time spent (% of observation time) on various behaviors in the three grouping treatments are shown in Figures 3 to 9.

Table 3. Mean and SE of time spent (% of observation time) on different behaviors and frequency of behaviors of sows housed in dynamic, 2-time mixing and static groups.

Behavior	Grouping treatment			P	Time points of observation			P
	dynamic	Two-time	Static		Mixing day	Day after mixing	Two weeks	
Total aggression	3.602 ± 0.461	4.481 ± 0.628	6.148 ± 1.169	NS	5.802± 1.163	3.534 ± 0.655	4.895 ± 0.509	NS
Queuing number	1.645 ± 0.172[a]	2.33 ± 0.286[b]	1.532 ± 0.187[a]	0.0218	1.991± 0.276	1.402± 0.177	2.114± 0.216	NS
Queuing duration	0.653 ± 0.144	0.723 ± 0.117	0.809 ± 0.121	NS	0.516± 0.096[a]	0.652±0.072[ab]	1.016±0.154[b]	0.0084
Non-agonistic social interactions	0.948 ± 0.153[a]	2.188 ± 0.332[ab]	3.254 ± 0.422[b]	0.0232	2.160 ± 0.394	1.905± 0.511	2.326± 0.360	NS
Non-social physical interactions / exploration	1.548 ± 0.193	1.954 ± 0.246	2.900 ± 0.601	NS	2.096± 0.572[ab]	1.499 ± 0.141[a]	2.807± 0.348[b]	0.0244
Stereotypies	0.761± 0.197	2.247 ± 0.344	2.067 ± 0.505	NS	0.926 ± 0.282[a]	1.477 ± 0.332[a]	2.672 ± 0.445[b]	0.0001
Sitting	0.406 ± 0.143	0.903 ± 0.316	1.112± 0.233	NS	0.819 ± 0.324	0.890 ± 0.274	0.822 ± 0.160	NS
Lying	7.051 ± 1.679[a]	17.056 ± 1.958[b]	26.709 ± 3.690[b]	0.0012	12.903 ± 2.587	19.301± 4.684	18.782± 2.593	NS
Standing	5.188 ± 0.634[a]	9.653 ± 0.942[b]	9.480 ± 0.844[b]	0.0014	7.438 ± 0.950[a]	6.371± 0.608[a]	10.512 ± 1.025[b]	0.0009
Walking	1.126 ± 0.127[a]	2.610 ± 0.332[bc]	1.985 ±0.157[ac]	0.0047	2.145 ± 0.289[a]	1.297 ± 0.140[b]	2.278± 0.312[a]	0.0005

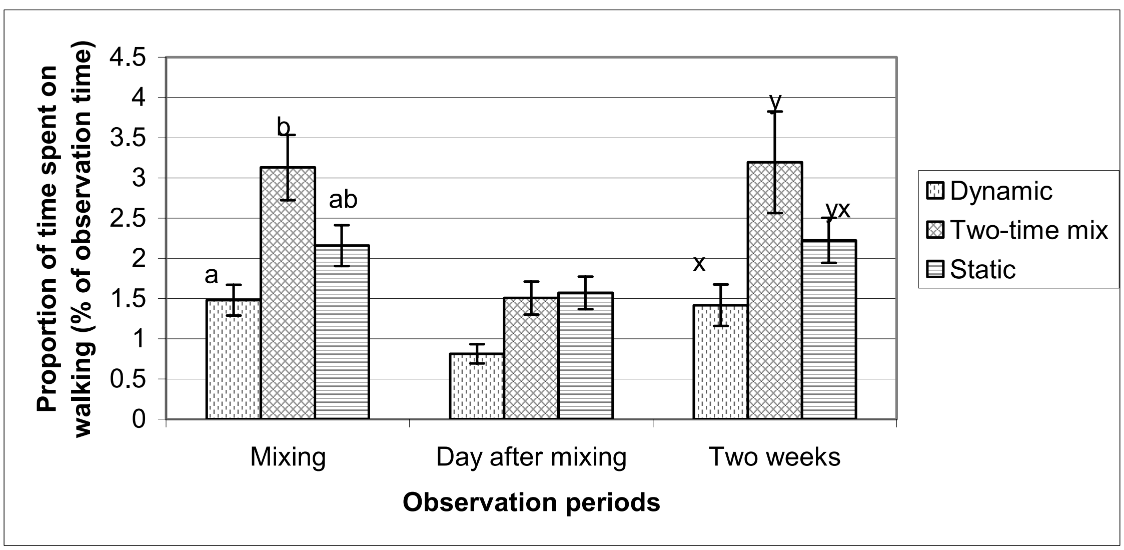
NS –Statistically not significant. [a,b,c] Within each row, values with different superscripts differ significantly in their means (P<0.05).

Figure 3: Proportion of time spent (% of observation time) lying (Mean and SE) in grouping treatments at observation time points



The proportions of time spent lying and walking varied (P<0.05) with the time point of observation among the grouping treatments (Figure 3 and Figure 4 respectively). The proportions of time spent lying was significantly higher in the static group on the day following mixing compared to the dynamic groups, though it was not different from that in the two-time mixing group (Figure 3). Similarly, the proportion of time spent walking was significantly (P<0.05) less in the dynamic group on the day of mixing and two weeks later, compared to those in the two-time mixing group though they were similar to that in the static group (Figure 4).

Figure 4: Proportion of time spent (% of observation time) walking (Mean and SE) in grouping treatments at observation time points



However, the proportions of time spent standing, sitting, stereotypic behavior, non-social physical interactions and queuing were similar among grouping treatments at different time points of observations (Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9 respectively).

Figure 5: Proportion of time spent (% of observation time) standing (Mean and SE) in grouping treatments at observation time points

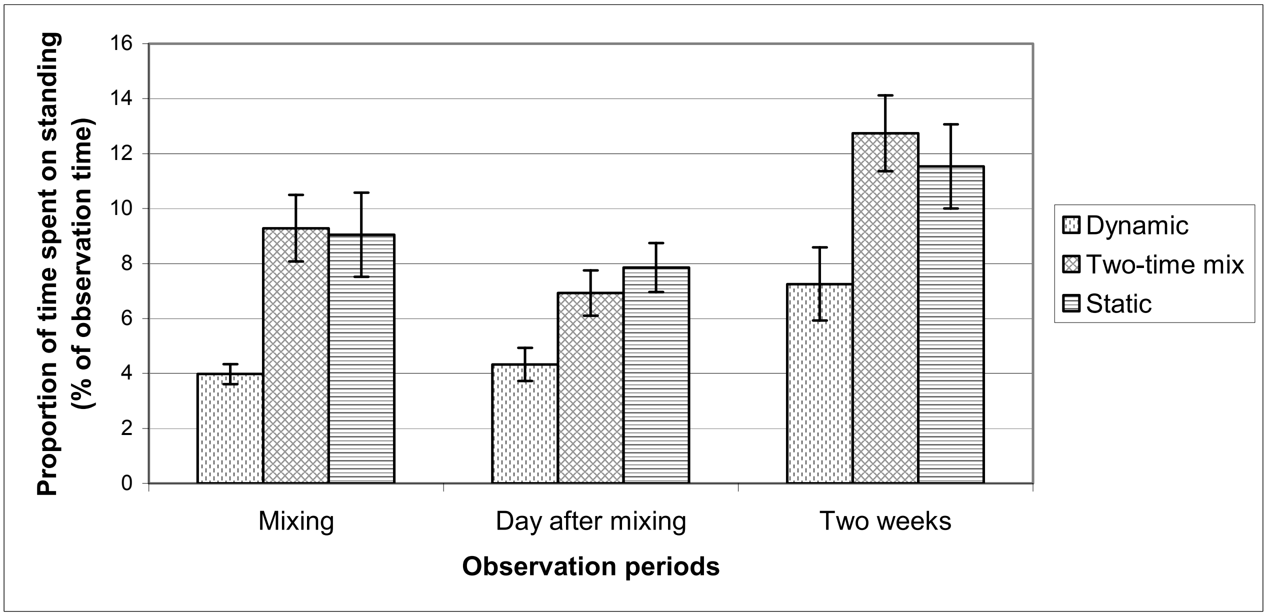


Figure 6: Proportion of time spent (% of observation time) sitting (Mean and SE) in grouping treatments at observation time points.

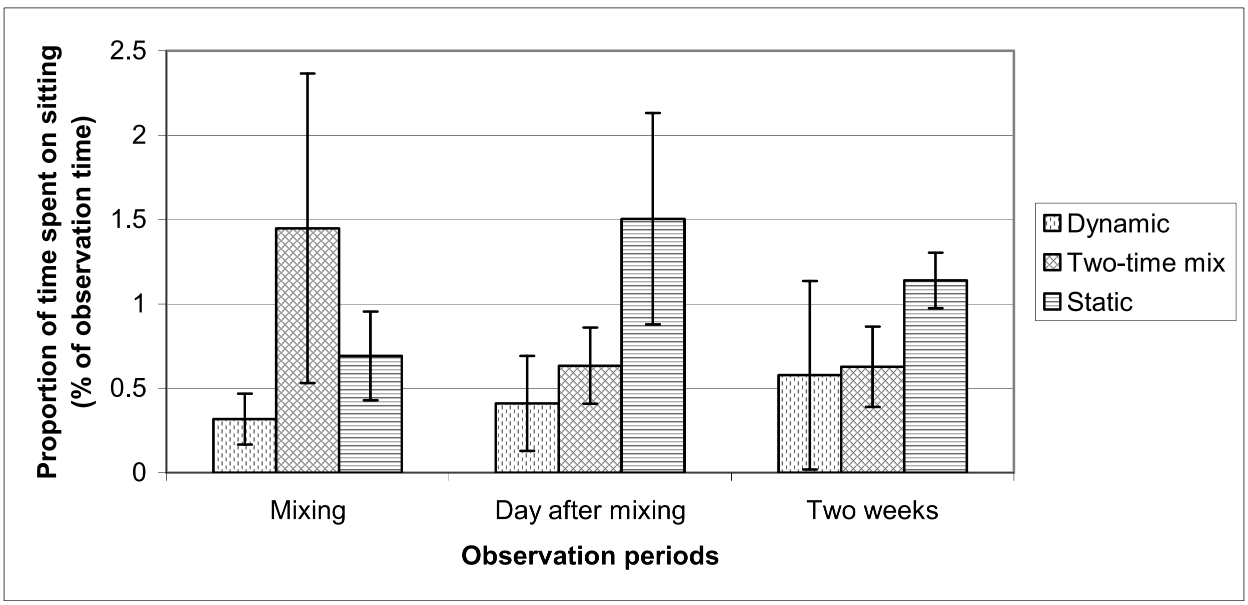


Figure 7: Proportion of time spent (% of observation time) on stereotypic behavior (Mean and SE) in grouping treatments at observation time points.

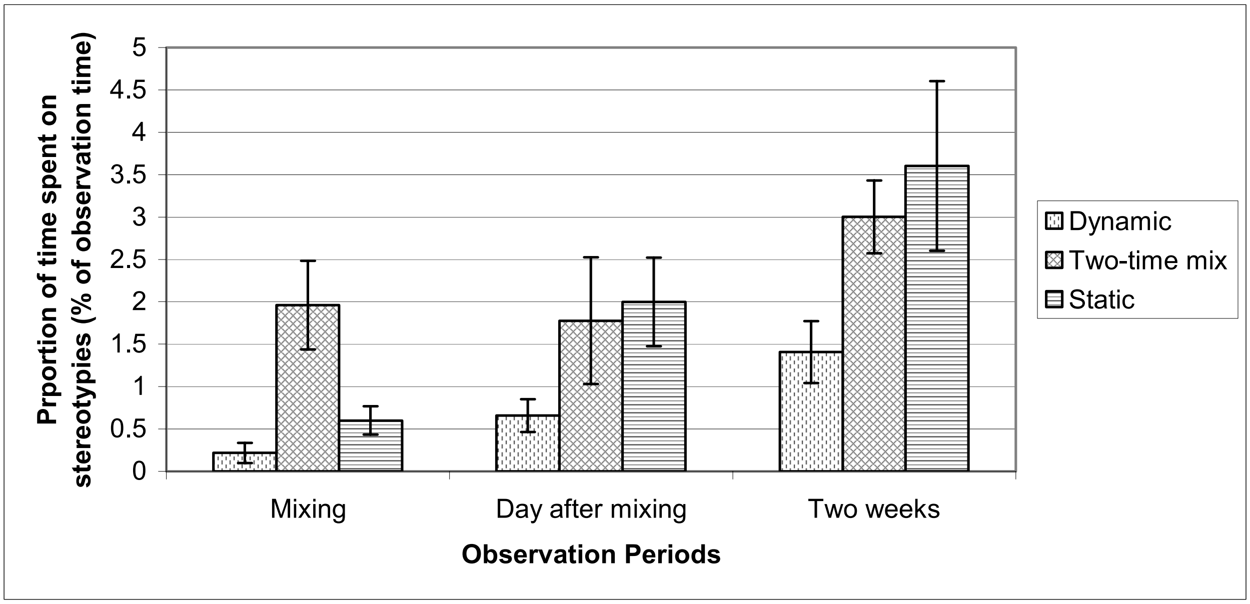


Figure 8: Proportion of time spent (% of observation time) on non-social physical interactions (Mean and SE) in grouping treatments at observation time points.

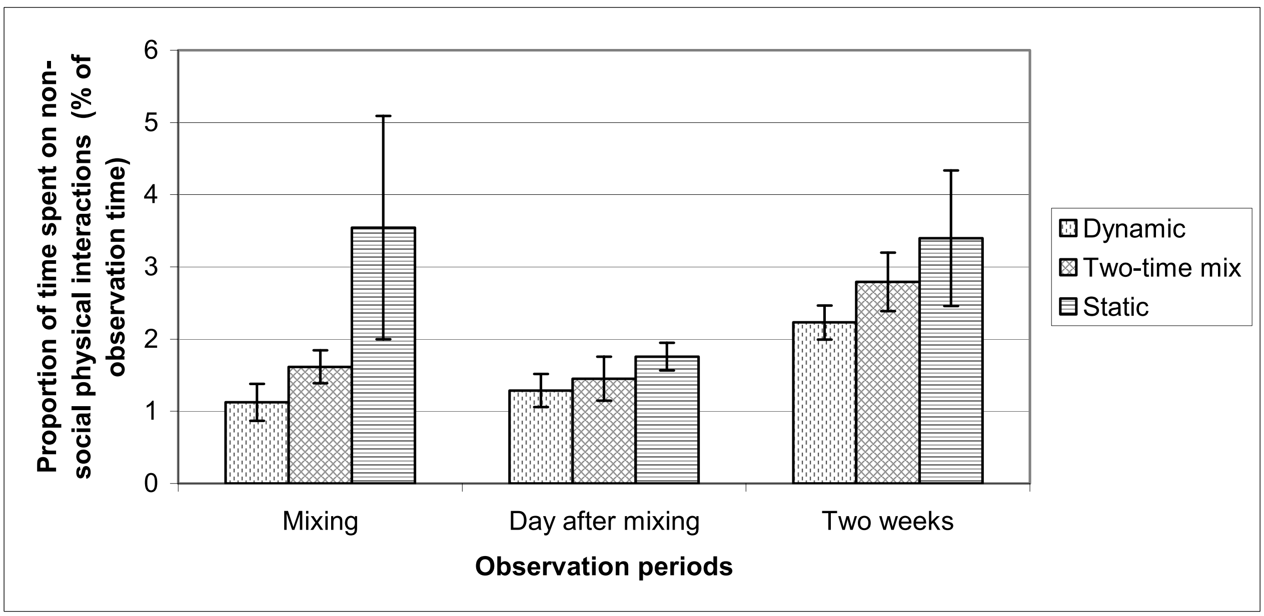


Figure 9: Proportion of time spent (% of observation time) queuing (Mean and SE) in grouping treatments at observation time points

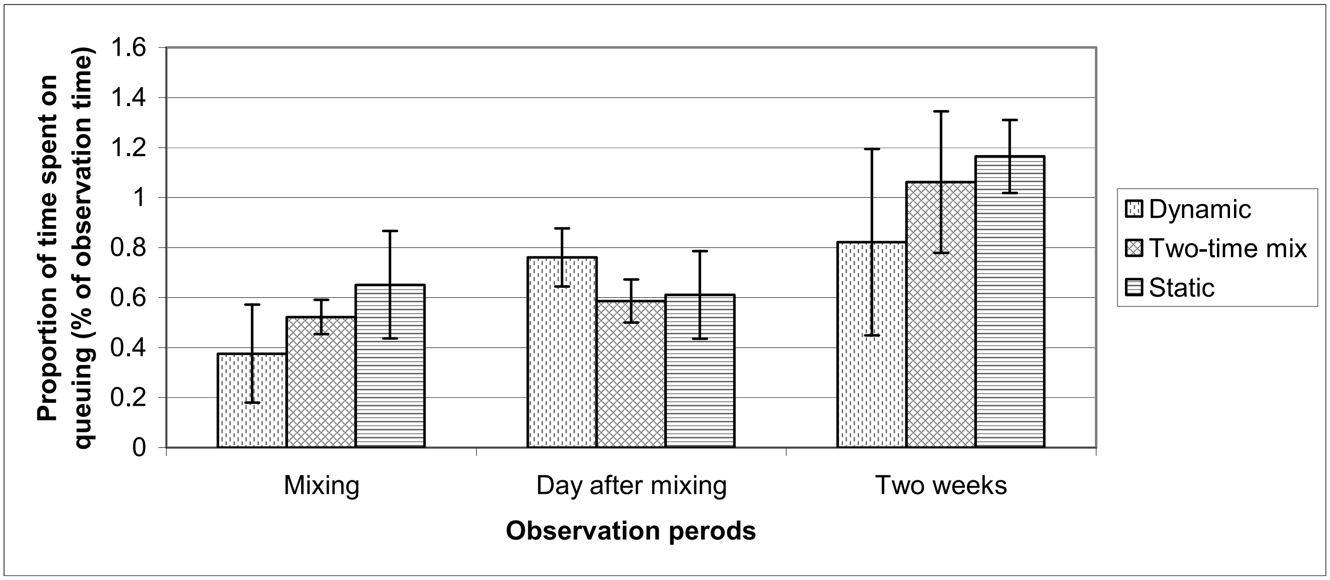


Table 4 presents the change over time in numbers of total aggression, queuing and non-agonistic social interactions among the grouping treatments. The numbers of total aggression, queuing and non-agonistic social interactions did not vary with the time point of observation among the grouping treatments (Table 4).

Cortisol concentration and TIS were positively and significantly ($P<0.05$) correlated in dynamic and two-time mixing groups (correlation coefficients 0.247 and 0.217 respectively) whereas, the association was not different in the static groups. Total aggression was positively correlated with number of queuing in the all the systems (correlation coefficients 0.477, 0.398 and 0.338 for dynamic, two-time mixing and static groups respectively, $P<0.001$ for all). The associations of total aggression with queue duration were significant and positive in dynamic and two-time mixing groups (correlation coefficients 0.418, $P<0.001$; 0.405, $P<0.001$ respectively). The association was also positive in the static group (correlation coefficient 0.156, $P<0.05$ one-tail). However, there was no differences for association between total aggression and cortisol concentration and between total aggression and TIS in any of the grouping treatments.

Table 4. Mean and SE of numbers of total aggressions, queuing and non-agonistic social interactions among the grouping systems at observation time points

Behavior	Mixing day			Day after mixing			Two weeks			P
	Dynamic	Two-time mix	Static	Dynamic	Two-time mix	Static	Dynamic	Two-time mix	Static	
Total aggression	3.248 ± 0.451	6.191 ± 0.525	7.968 ± 3.258	2.704 ± 0.505	2.341 ± 0.443	5.556 ± 1.481	4.854 ± 1.021	4.910 ± 1.142	4.919 ± 0.710	NS
Queuing	1.387 ± 0.349	3.046 ± 0.351	1.537 ± 0.183	1.549 ± 0.123	1.718 ± 0.379	0.938 ± 0.271	1.998 ± 0.349	2.225 ± 0.580	2.119 ± 0.216	NS
Non-agonistic social interactions	1.080 ± 0.187	0.262 ± 0.697	2.74 ± 0.776	0.602 ± 0.306	1.559 ± 0.429	3.554 ± 1.038	1.163 ± 0.262	2.350 ± 0.571	3.464 ± 0.387	NS

NS –Statistically not significant

Population and performance details
Table 5 and Table 6 present the population details and performance of sows in three grouping treatments respectively. There was no (P > 0.05) difference in the farrowing performance and longevity of sows in the grouping treatments studied. However, the percentage of sows farrowed was higher in the static group. Though not different from others, the number of death and euthanasia was higher in the dynamic group. Similarly, the number of piglets born alive and the number of pigs weaned were more in the static group though they were not different from the other groups.

Table 5. Details of the population and longevity of sows housed in dynamic, two-time mixing and in static groups.

Population details	Dynamic	Two-time mixing	Static	p
Number allocated	98	109	103	
Number of animals farrowed	71	80	83	
Farrowed (%)	72.45	73.39	80.58	NS
% farrowed out of live animals(excluding removals)	71/87=81.61	80/101=80.2	83/94=88.3	NS
Culling due to productivity	3	4	5	
Culling due to lameness	-	-	1	
Death	1	0	2	
Euthanasia	4	3	1	
Removal to stall	2	1		
Total removal	11	8	9	NS
Abortion	2	-	1	
Return before 45 days	16	12	8	
Return after 45 days	2	13	6	
Total number of returns	18	25	14	NS
Incidence of lameness and downers	7	4	2	

NS –Statistically not significant

Table 6: Details of the performance of sows housed in stable, 2-time mix and dynamic groups

Performance measures	Dynamic		Two-time mixing		Static		
	Mean ± SE	Median and range	Mean ± SE	Median and range	Mean ± SE	Median and range	
Born alive	10.211 ± 0.382	11 (0-15)	10.137 ± 0.325	10 (4-16)	10.892 ± 0.284	11 (5-17)	NS
Pigs weaned	9.085 ± 0.259	10 (0-11)	9.188 ± 0.140	10 (4-11)	9.434 ± 0.220	10 (0-11)	NS
Piglet death	1.211 ± 0.149	1 (0-6)	1.138 ± 0.162	1 (0-8)	1.265 ± 0.175	1 (0-8)	NS
Litter birth weight	35.206 ± 1.244		35.956 ± 1.061		37.912 ± 0.858		NS
Wean weight of piglets	133.61 ± 4.044		133.64 ± 2.425		133.23 ± 3.666		NS
Mummies / litter	0.268 ± 0.078	0 (0-4)	0.213 ± 0.055	0 (0-2)	0.337 ± 0.073	0 (0-3)	NS
Still born / litter	1.000 ± 0.189	0 (0-9)	1.000 ± 0.169	1 (0-8)	0.566 ± 0.093	0 (0-4)	NS
Foster on / litter	0.930 ± 0.185	0 (0-6)	1.088 ± 0.160	0.5 (0-6)	0.964 + 0.154	0 (0-7)	NS
Foster off /litter	0.845 ± 0.156	0 (0-5)	0.900 ± 0.157	0 (0-5)	1.171 ± 0.218	0 (0-12)	NS
Weight of sows weaning (kg)	221.332 ± 3.639		222.534 ± 3.244		227.306 ± 2.870		NS
Weight of sows at 109 days (kg)	229.930 ± 3.009		229.847 ± 2.512		236.227 ± 2.192		NS
Backfat of sows at weaning (mm)	18.338 ± 0.428		19.269 ± 0.450		18.151 ± 0.407		NS
Backfat sows at 109 days (mm)	18.444 ± 0.464		19.413 ± 0.465		19.645 ± 0.398		NS
Weight gain during gestation (kg)	8.598 ± 2.198		7.313 ± 1.752		8.921 ± 1.925		NS
Gestation length	115.859 ± 0.186		116.113 ± 0.152		115.687 ± 0.138		
Lactation length	18.775 ± 0.506		18.938 ± 0.148		18.663 ± 0.327		
Wean to service interval	5.739 ± 0.430		5.566 ± 0.405		5.358 ± 0.239		

NS –Statistically not significant

Economics
Analysis of the time budget for different routine management indicated that 3.4, 6 and 11 minutes per farrowed sow per gestation were required in the static, two-time mixing and dynamic groups respectively. The time periods for pen preparation prior to the start of the experiment, repairing one ESF in the dynamic groups, control access to the feeder gate in the static groups and weighing and backfat measurement were not included in the analysis. There was little difference in cost of penning or space used.

Discussion: The major factors associated with the causation of stress and injuries in the groups studied were the aggression consequent to mixing and competition for feeder entry. It has been suggested that unfamiliar animals and amount and distribution of resources can influence dominance aggression, competitive aggression and defensive or protective aggression in pigs (Giersing and Studnitz, 1996). In the present study, the competition for feeder entry was ever present in all groups as feed was restricted. In addition, social facilitation might have motivated sows to enter the feeder (Gonyou *et al*., 1992) even after receiving the daily allotment leading to a competition to enter the feeder. Social facilitation has reported to increase feeding motivation (Olsson *et al*., 1986; van Putten and Van de Burgwal, 1990; Bure, 1991; Allen *et al*., 2002). The comparison of cortisol and injury levels (Table 2) at different time points regardless of the grouping treatment suggests that mixing was a major stress factor.

High levels of aggression during the first 24h after regrouping in dynamic group for pregnant sows as observed in the present study have been previously reported (Bokma and Kersjes, 1988; Hunter *et al*., 1989). An increase in agonistic behavior following introduction of new pigs into an established group in order to establish a new social ranking has been reported by Ewbank and Meese (1971) also. Similarly, aggressions during mixing has been reported to increase cortisol in pigs (Parrott and Misson 1989). In the present study also the cortisol level, regardless of the grouping treatment was higher following mixing (Table 2). The injury scores despite the time points (Table 1) were higher in the dynamic group since sows in that group were exposed to unfamiliar animals more often. Further, the number of sows was also more in this group requiring the sows to have more number of hierarchies established. Once hierarchy is established after mixing unfamiliar sows, agonistic interactions reduce in frequency and intensity (Hessing, 1993) and the subordinate sows tend to avoid dominant sows rather than the dominant sows attacking the submissive ones (Jensen, 1980; Jensen, 1982). In the present study, unfamiliar sows were added to the existing group in the case of the dynamic group whereas there was no further addition of sows to the static group, reducing the injury scores in the static group at 2 weeks post-mixing as shown in Figure 2. However, one more batch of sows was added to the two-time mixing group causing aggressive encounters among the members of that group and thus the TIS at 2 weeks post-mixing in that group was not different from that of the dynamic group. It should also be noted that, the TIS at 2 weeks post mixing was similar in the two-time mixing group and in the static group. It is important for the submissive sows to have needed space within the pen to retreat from the dominant sow at the time of aggressive encounters (Weng *et al*., 1998) and to regulate social stability (Jensen, 1982). Baxter (1985) has reported that sows should be able to distance themselves at least 4-5 body lengths from one another when unfamiliar sows are mixed. Though the space per sow was the same in all the grouping treatments, the total available free space was less in the static group.

It has been reported that sows may be chased up to 20 meters (Edwards *et al*., 1986). Thus, the lack of space could have minimized the chances of lower injury score in the static group.

As mentioned before, after the initial aggression following the introduction of new animals, a hierarchy is established which will exert a great influence in the way in which the sows in the group behave. It may take between three and 10 days before a hierarchy is established after mixing unfamiliar sows (Van Putten and Ven de Burgwal, 1990; Oldigs *et al*., 1992). Nevertheless, other reports (Moore *et al*., 1993; Spoolder *et al*., 1996) have indicated that random intermingling of individuals from two groups does not occur until after 21 days. As suggested by Arey (1999) the formation of group stability is more of a progressive process than a discrete event. Group stability may be affected by the degree of competition for resources as well (Arey and Edward, 1998). In the present study, observations on injury levels were collected on the day following mixing and 2 weeks later. It may be likely that despite a reduction in aggressive interactions, the group stability was not fully attained within 14 days after mixing, especially because feed remained as a limited resource. In larger groups, similar to the dynamic group in the present study, sows may have difficulty in recognizing one another to form a stable hierarchy (Petherick and Blackshaw, 1987).

The lower TIS in static group compared to dynamic group at 2 weeks after mixing (Figure 2) may be because in the static group the number of sows was less and thus there were only less number of linear hierarchies to be established. There will be more fighting in larger groups because more hierarchy positions are to be decided (Arey and Edwards, 1998). The complexity of inter-individual dominance relationship and intensity of interactions increases with increase in group size (Lindberg, 2001). Smaller groups are reported to have lower overall rates of aggressive interactions (Drickamer *et al*., 1999). The present finding is in agreement with previous findings on the relationship between group size and rates of aggression (Bryant and Ewbank, 1972; Ewbank and Bryant, 1972). The general activity level will be higher in larger groups which results in more encounters between animals and increased aggression (Petherick and Blackshaw, 1987). Further, unlike in the two-time mixing group where the first batch of sows are added to an empty pen followed by a second batch of sows added 2 weeks later, in the dynamic group, a batch of sows was added to an existing group of 78 followed by the second batch 2 weeks later when another batch of sows in advanced gestation was sent to the farrowing stall and so on. Thus, the equilibrium in the dynamic group was disturbed not only by the addition of sows but also by the removal of sows. Therefore, the number and intensity of interactions were more in the dynamic group. Consequently, the number of non-agonistic social interactions was also less in the dynamic group compared to the static group (Table 3). The grouping structure and increased agonistic interactions might also explain the lower proportion of time spent lying by the sows in the dynamic group compared to the other groups studied.

The ratio of new to resident animals is important factor influencing the level of aggression (Moore *et al*., 1993) which was higher in the dynamic group. As noted before, although overt aggression is reduced, random intermingling of animals after mixing unfamiliar animals may take up to 21 days of time. In the present study, the final data were collected 2 weeks after mixing. Also, feed was a limited resource and the cameras were focused on areas of the pen mainly at and around the feeder. Thus, it is conceivable that the focal animals (those were always from the newly introduced batch) were unable to stay more time at and around the feeder. Hodgkiss *et al*., (1998) has observed that majority of the agonistic interactions occurred in lying areas and near the feeder. Broom *et al*., (1995) have also reported that aggression is often localized around food. This is another reason explaining the lower numbers of queuing, non-agonistic social interactions and lower durations of lying, standing and walking recorded in the present study among the sows in the dynamic group (Table 3). Although similar conditions were present in the two-time mixing system, the total number of animals and the ratio of new to resident animals was less in that group.

In the present study, the dynamic group was formed by adding batches of sows each to an existing group of sows at bi-weekly intervals. As has been reported, the existing sows have dominance over the newly added sows (Mendl *et al*., 1993). The focal sows in the dynamic group whose behavior was recorded were from the newly added batch and had less chance to form queues at the feeder entry compared to the focal sows in the two- time mixing group (Table 3). Social isolation and avoidance of the feed station by the new animals during the initial 24-48h after regrouping has been observed by Hunter *et al*., (1989) and Moore *et al*., 1989). In the two-time mixing group also the focal sows were from the newly added batch, however, the total number of sows was less in that group. Although sub-group formation was noticed in the dynamic group, it was mainly visible in lying behavior. The number of queuing was also low in the static group compared to the two-time mixing group, but for different reasons. The static group in the present study was formed by partitioning an existing pen. The feeder entry was permitted only for 12h in this group unlike in the other groups and thus the total time for observing the sows for queuing was less in this system. The lesser number of sows in the static group could have also lowered the number of queuing in this system. The higher number of aggressive encounters might have lowered the number of non-agonistic social interactions and durations of lying, standing and walking in the dynamic housing system regardless of the time points of data collection (Table 3). Similarly, the intense agonistic interaction could have been responsible for the lesser durations of queuing, stereotypies, standing and walking observed at the time of mixing compared to that of 2 weeks later in this study regardless of the grouping treatment (Table 3).

The intense fighting to establish hierarchy diminishes 24 h after mixing (Moore *et al*., 1993) and 2 weeks later a stable equilibrium is likely to have been established. In the present study also, sub-group formation was visible by 2 weeks. However, this was apparent only in lying. The proportion of time spent lying by sows in different housing systems were similar (Figure 3) at mixing and 2 weeks after mixing because the conditions (intense fighting, subgroup formation/ stabilization) were similar at these stages. However the proportion of time spent lying by sows in the dynamic group was less than that by sows in the static group the day following mixing (Figure 3). This is may be due to continuing aggression in the dynamic group because of the high ratio of new to resident sows in that system. The same explanation applies to significantly lower proportion of time spent on walking by the sows in the dynamic group at mixing (Figure 4). The proportion of time spent walking was lower among the sows in the dynamic groups at 2 weeks after mixing (Figure 4) as well suggesting that, though overt aggression has diminished sows have not yet been able to freely intermingle and use the resources. However, Rushen (2003) has suggested that resting behaviors such as lying are highly variable among sows in housing systems. It is also difficult to suggest a point beyond which welfare is likely to be compromised.

Injuries in group systems are produced by aggression. An aggression sufficient to cause injuries is likely to have elicited cortisol release. Aggressions occurring at the time of mixing are generally severe as it is part of the effort to establish a hierarchy. The intensity and number of such aggressive interactions were more in the dynamic and two-time mixing groups compared to the static group because of the higher number of sows. The positive correlations between cortisol concentrations and TIS in these systems support this. However, all aggressions, for instance, those exhibited after the initial mixing are not very severe ones as they are performed to mainly to maintain the hierarchy. Once hierarchy is established agonistic interactions reduce in frequency and intensity (Hessing, 1993) and the subordinate sows tended to avoid dominant sows rather than the dominant sows attacking the submissive ones (Jensen, 1980; Jensen, 1982). Therefore, such aggressions may not result in higher injuries or stress level as indicated by the non-significant coefficients obtained for the correlations of total aggressions with cortisol and aggressions. After mixing, the major source of aggression in a feed restricted environment in group houses are feeder related. This is confirmed in the present study by the significant positive correlations of total aggression with number and duration of queuing. Olsson *et al*., (1992) have also suggested an association between queue formation and number of conflicts.

The reproductive performances of sows were similar in all the groups studied although the number of times sows were exposed to unfamiliar sows was different in different groups. One major factor affecting the performance of sows in group houses is the aggression occurring around the time of implantation. Arey and Edwards (1998) have reported that grouping prior to the implantation period resulted in a reduction in litter size of 0.6 piglets (11.8 v 12.4, $P<0.05$), although conception rate was not affected. Grouping and fighting after mating may increase physiological stress and adversely affect reproductive performance (Bokma 1990; Arey and Edward, 1998). In the present study, all sows were moved to their respective housing systems prior to implantation and all were exposed to aggression associated with mixing and feeder. This may be why there was no difference in the reproductive performance of sows in different grouping treatments.

Although the static group required only less time for routine management, it required additional labor for controlling access to the feeder which was not included for the present analysis. The dynamic group obviously demands more labor for inspection and management because of the higher number of sows in it. Thus, the two-time mixing group appeared to be the manageable grouping under the conditions of the study.

Lay interpretation: The present research was an attempt to see how the existing system of commercial group houses with ESF can be made more welfare friendly by modifying the group size and structure. The groups studied showed no difference in terms of major welfare indicators such as cortisol concentrations and number of total aggressive interactions. However, total injury scores were higher and number of non-agonistic social interactions was lower in the dynamic group suggesting that the welfare of sows in the dynamic group was compromised compared to the other groups. The production performance of sows was also similar among the groups. Although, subgroup formation was visible in dynamic group it was apparent only in lying behavior during the period of the study. However, free intermingling of sows might have happened later during their stay in the group. The time required for routine management was higher in the dynamic group. As observed in the present study and in many previous studies, aggression at mixing and competition for feeder entry are the major threats to the welfare of sows in group systems with ESF. It may not be possible to improve the system without addressing these issues. Changing the group size and structure alone may not bring in better welfare. Pen and feeder designs are crucial along with measures to reduce aggression at mixing and hunger. Ensuring control of access to the feeder at the gate rather than only at the point of feed delivery may reduce the aggression associated with feeder entry. Similarly, providing manipulable materials such as a small quantity of straw may help to divert the attention of sows at mixing and may reduce hunger to some extent. Pre-exposure of sows by maintaining sub-groups of sows in adjacent pens may reduce aggression at mixing.

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