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A comparison of the welfare of sows in different housing conditions

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Abstract

Twelve sows in good quality unstrawed stalls, three groups of five sows in strawed pens with individual feeding stalls and sows in a 38-sow group in a strawed yard with an electronic sow feeder were compared during the first four parities. They originated from the same source, were about 9 months of age and in the 7th week of their first pregnancy at the start of the experiment and were kept in adjacent rooms in a building, cared for by the same staff and given the same diets at a rate of 2·2 kg/day per animal. No new animals were added to the groups or stalls during the study and animals returned to the same condition after periods in farrowing and service accommodation. Using a wide range of welfare indicators, it was clear that stall-housed sows had more problems than group-housed sows and that these problems were worse in the fourth than in the first pregnancy. By the fourth pregnancy, stall-housed sows spent proportionately 0·14 of time showing activities which were clearly stereotypies and much time on activities which were sometimes stereotyped, i.e. 'drinking' and rooting or chewing at pen fittings making a total of proportionately 0·50 of time. Comparable figures for group-housed sows were much lower (0·037 and 0·081 in total). Stall-housed sows were also more aggressive than group-housed by the fourth pregnancy and their body weights were lower. There were no differences using physiological or immunological tests or measures of reproductive output. When the two group-housing systems were compared, sows in the electronic feeder system showed more fighting, especially soon after initial mixing, but fewer total agonistic interactions than sows in groups of five during the first pregnancy. Oral stereotypies were slightly higher in small groups, perhaps because of smaller pen space, than in larger groups but much lower than in stalls. By the fourth pregnancy there were few differences between sows in small and large groups and all seemed to have adapted well to the conditions. Evaluation of welfare in different housing systems requires use of a wide range of measures and of long-term studies.

Keywords: *behaviour, housing, sows, welfare.*

Introduction

On modern farms throughout much of the world, pregnant pigs are housed singly in a space of about 2 m × 0·6 m. They are either enclosed in this space by a metal cage (stall), or they are restrained by a tethering chain attached to a collar around their neck or girth. Tethered and stall-housed pigs cannot turn around and are generally prevented from performing many of the behaviour patterns that pigs perform in less restricted conditions (e.g. rooting, complex social behaviour). There are various indications that the welfare of pigs kept in these conditions is poor (e.g. Broom, 1989; Fraser and Broom, 1990), and there has been public concern about the systems for many years (e.g. Harrison, 1964). Several countries, e.g. Sweden, Norway, Switzerland, have banned or intend to ban the use of these housing systems and the United Kingdom government has recently announced that it is to do so from 1999 onwards. As a result, group-housing systems for pregnant pigs will have to replace stalls and tethers. It is thus important that these systems are designed and managed so that the sows' welfare is good.

The welfare of pigs housed in various types of dry sow accommodation has been compared in a number of experimenal studies. In most of these, pigs housed

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in stalls or tethers have been compared with those housed in small groups of between two and ten (e.g. Vestergaard and Hansen, 1984; von Borell and Ladewig, 1989). In some of these studies, the pigs were not pregnant (e.g. Barnett, Cronin, Winfield and Dewar, 1984), and in many the subjects were pigs in their first pregnancy (e.g. Barnett, Winfield, Cronin, Hemsworth and Dewar, 1985; Barnett, Hemsworth, Winfield and Fahy, 1987a; Arrelano, Pijoan, Jacobson and Algers, 1992; Rampacek, Kraeling, Fonda and Barb, 1984). By focussing on gilts, most of these studies have provided information about the initial responses to the housing conditions, but there are fewer data relating to the long-term effects of housing systems on sow welfare. This is regrettable in view of the fact that pigs are older for most of the time in these systems. The present study was designed to start to fill this gap in our knowledge by following pigs from early life until their fourth pregnancy in three different housing systems. In addition, the study allowed a long-term evaluation of the consequences for welfare of the electronic sow feeder system, a group-housing system which is growing in importance in several countries (Edwards and Riley, 1986; Hunter, Broom, Edwards and Sibly, 1988; Mendl, Zanella and Broom, 1992b). This system usually accommodates considerably more sows than the group-housing systems studied in previous research, so it is important to examine how well sows are able to cope with these larger group sizes.

Sows housed in an electronic sow feeder system were compared with those housed in groups of five per group with access to individual feeders, and to those housed in conventional stalls. All three systems were newly built to high quality commercial specifications, adjacent to each other in identical sections of a building. All sows were given the same diet and looked after by the same stockmen in order to minimize the effects that food and stockmanship may exert on the responses of pigs to husbandry and housing conditions (Hemsworth, Barnett, Coleman and Hansen, 1989; Rushen and de Passillé, 1992).

A longitudinal experimental design was used to obtain information on how the pigs responded to their initial introduction to the three housing systems (during the first pregnancy), and how they adjusted to the systems over time. A variety of measures, which can be used as indicators of animal welfare (Broom, 1988; Broom and Johnson, 1993), were used during the first and fourth pregnancies. These included measures of stereotypies, aggression, responsiveness, pituitary-adrenal function, immune system function, growth rate and reproductive success.

Material and methods

Animals, housing, feeding and general management

The subjects were 65 undocked Large White × Landrace (Masterbreeders, Tring, UK) sows (hereafter, for ease of presentation, all experimental female pigs will be referred to as sows irrespective of their age or parity number).

All sows were individually identifiable by ear tatoos and tags. They were born during a 12-week period and were reared in four batches from birth until their first pregnancy. The sows were introduced into the three housing systems when they were about 9 months old and in the 7th week of their first pregnancy. The small group animals came from the first two batches, the stall animals from the last two batches and the ESF animals from all batches. The stall animals were taken from the last two batches, rather than the first and fourth as planned because of a building delay and so were a little older than the small group animals on entry to the system.

Twelve sows were housed without bedding in conventional, part-slatted stalls with an insulated floor (2 m × 0·6 m). Three groups of five sows were housed in identical pens comprising a strawed lying area (3 m × 2·2 m), a dunging area (2 m × 2·2 m) and five individual feeding stalls. Sows in these two systems (stalls and small groups) were given food once daily at about 10.30 h, and water was available *ad libitum*. The diet was Dalgety Ultrabreed 16 nuts, ref. 383 (160 g protein, 65 g oil, 60 g fibre, 65 g ash per kg) and the quantity offered was 2·2 kg/day, considerably less than would be eaten if food were offered *ad libitum*. All sows were given a mean of 7·7 kg/day of the same diet during lactation and 3·2 kg/day in service accommodation. Throughout the study any sow which was in poor condition was given extra food until her condition recovered. On most occasions where this was necessary the sows were those in stalls. The remaining 38 sows were housed in a large pen divided into a strawed lying area (11·4 m × 5·5 m) and a dunging area (5·1 m × 5·5 m). Part of the lying area included a free standing wall, behind which chased sows could hide, and two gates which could form a pen if needed. Part of the dunging area was occupied by an electronic sow feeder unit (crate manufactured by Quality Equipment, Bury St Edmunds, UK and electronics by Nedap Poiesz, Hengelo, Netherlands) in which the sows could feed themselves, one at a time. This front exit, sow operated feeder with an exit race was chosen after a considerable amount of investigation as the best available. The feeding cycle started at 15.00 h. This system (electronic sow feeder = ESF) was set so that each sow could obtain, and normally did obtain, 2·2 kg food each day. Water was available *ad libitum*. Each system was ventilated by thermostatically controlled 900 r.p.m. 45-cm fans (one fan in each of the stall and small group systems and two fans in the electronic sow feeder system). Supplementary heating was used during cold weather, in particular to compensate for increased likelihood of body heat loss in the stall-house. The pens were illuminated both by natural daylight and artificial lighting with lights switched on at 06.00 h and off at 22.00 h. The dunging areas of each system were cleaned daily and straw was added to the lying areas of the group-housing systems at regular intervals.

General experimental protocol

The behaviour of each sow was observed on 3 days during the 1st week following entry to the housing systems and on 2 days during the 3rd week. During the 5th week, each sow was subjected to a dexamethasone suppression and adrenocorticotrophic hormone challenge test to examine pituitary-adrenal activity. Each sow's humoral immunocompetence was also studied by measuring serum IgG antibody response to the *Bordetella* bacterium component of an atrophic rhinitis vaccine. A baseline blood sample was taken 1 or 2 days prior to entry to the housing system and this was immediately followed by administration of the vaccine. During the 6th week following entry, a second blood sample was taken followed by a second vaccination. A third blood sample was taken 6 weeks after this (during lactation). The first and third blood samples were also used for blood haematology and biochemistry analysis.

All sows remained in the same housing systems except when in farrowing or service accommodation. During their fourth pregnancy, their behaviour was observed again for 5 days and a dexamethasone suppression and adrenocorticotrophic hormone challenge test was administered during the 10th to 11th week of pregnancy. To assess the responsiveness of the sows to external stimuli, a tail withdrawal test was carried out on 3 days during the fourth pregnancy.

Sows were removed to farrowing accommodation 3 to 7 days before farrowing. Sows from each system were allocated in equal proportions to farrowing crates and farrowing pens. Piglets were weaned at 21 to 24 days and sows were put in large individual service pens where they were kept for approximately 1 week for service.

All sows were weighed 1 or 2 days before entry to the housing systems during the first pregnancy, 1 month after entry, just before parturition, and just after they had been removed from their first litter. Subsequently, they were weighed before each parturition and after each resulting litter had been removed. Reproductive performance was assessed at each parturition.

Behavioural observations

All observations were made from platforms 2 to 3 m high. The observer kept as quiet and still as possible and interruptions by farm staff or others were minimized. For observation purposes, a number was sprayed on the back and flanks of each sow. The method of data collection for all three housing conditions was that on each observation day, the sows were observed four times, once in each of the following time periods: 08.30 to 10.00 h, 11.30 to 13.00 h, 14.00 to 15.30 h, 16.00 to 17.30 h. Hence there was an observation period before feeding (08.30 to 10.00 h) for the stall and small group sows, before the start of the feeding cycle (14.00 to 15.00 h) for ESF sows, after feeding (11.30 to 13.00 h) for the stall and small group sows and after the start of the feeding cycle (15.00 to 15.30 h and 16.00 to 17.30 h) for ESF sows. In addition there were observations twice at times when little or no feeding occurred, (14.00 to 15.30 h and 16.00 to 17.30 h) for the stall and small group sows, (08.30 to 10.00 h and 11.30 to 13.00 h) for the ESF sows. No systematic observations were made during the light evenings or periods of darkness but visits at those times indicated that activity levels were lower then and aggressive interactions were rarer. During the fourth pregnancy, in the small groups observation periods occurred a mean of 5 weeks after reintroduction of sows which had been served whilst in the ESF, observation was a mean of 2 weeks after the inevitably more frequent reintroductions.

A combination of focal animals, instantaneous sampling and behaviour sampling techniques was used (Martin and Bateson, 1993) but every sow in each condition was observed. During the first pregnancy, the following sampling procedure was used. All sows in a batch were focal sampled during each watch. At the start of a watch, all focal sows were instantaneously sampled. The first focal sow was then observed continuously for 2 min and this was followed by an instantaneous sample of its behaviour. The next focal sow was then observed in the same way until the whole batch had been observed. A further instantaneous sample of all focal sows was then made, and the whole procedure was repeated three more times giving 8 min focal sampling per sow per watch, and 32 min on each of the 5 days of observation. During the fourth pregnancy, the sampling procedure remained the same except that each focal sow was observed for three 3-min sessions giving a total of 9 min of observation per focal sow per watch period and 36 min on each of the 5 days of observation. All agonistic and non-agonistic interactions (defined below) in which the current focal sow was involved were recorded. In addition, throughout the watch, all agonistic interactions, including those not involving the current focal sow, were also recorded. This was possible since nearly all of these interactions were accompanied by vocalizations or rapid locomotor movements which could be detected easily by the observer.

The instantaneous sampling technique provided information about the proportion of observation time that each sow spent in specific behavioural states. These included inactive (lying still with eyes open or closed), performing oral behaviour (rooting or chewing at pen fittings or straw/floor, sham-chewing), performing social behaviour, performing maintenance behaviour (drinking, scratching, urinating, defaecating), and sitting, standing or moving. The focal sow and behaviour sampling techniques provided information about the frequency and duration of specific behavioural events including the occurrence of stereotypies such as sham-chewing, bar-biting and trough-biting behaviour, and the occurrence of agonistic social interactions (knocking, biting, threatening or chasing behaviour, or active avoidance without contact), non-agonistic interactions (nosing, chewing or belly-nosing behaviour) and fights (agonistic behaviour involving repeated physical contact and lasting longer than 5 s). It was also possible to determine the proportion of agonistic interactions which had a clear outcome (successful displacement of one sow by another) and which escalated beyond a simple initiation and response. Full details of recording methods are given in Mendl *et al.* (1992b).

Tests of pituitary-adrenal function

Pituitary-adrenal function was assessed using dexamethasone (DXM) suppression and adrenocorticotrophic hormone (ACTH) challenge tests. These tests are of use in assessing the functional state of the system which may, in turn, reflect the psychological state and experiences of the individual during the preceding few days or weeks. Decreased sensitivity to the suppressive effects of DXM (a synthetic glucocorticoid) on ACTH and cortisol production is often seen in depressed or stressed individuals (e.g. Meunier-Salaun, Vantrimponte, Raab and Dantzer, 1987; Haracz, Minor, Wilkins and Zimmermann, 1988; Mendl, Zanella and Broom, 1992a). A high maximal response to ACTH is often seen in individuals who have recently been exposed to certain types of chronic stress (Dantzer, Mormède and Henry, 1983; von Borell and Ladewig, 1989; Mendl *et al.*, 1992b). These tests were carried out *in situ* in the pens and started at about 13.30 h. The tests differed slightly in the first and fourth pregnancies, but followed the same basic protocol. An initial sample was collected prior to the first injection of DXM (Merck, Sharp and Dohme, Hoddesdon, UK; first parity: 0·02 mg/kg intra-venous; fourth parity: 0·1 mg/kg intra-venous). Two h later, the ACTH injection ('Synacthen', CIBA, Horsham, UK) was given (first parity: 4 µg/kg intra-muscular; fourth parity: 5 µg/kg intra-venous). Samples were collected for 4 h from the DXM injection (first parity: 1 per h; fourth parity: 1 per 20 min). At both pregnancies, saliva samples were collected. Saliva was collected by stimulating the sows to chew on a veterinary cotton bud for 15 to 20 s. Between 0·5 and 1 ml was obtained from most sows. Salivary cortisol was measured using an enzyme-linked immunosorbent assay (Cooper, Trunkfield, Zanella and Booth, 1989). In the fourth pregnancy, plasma samples were also collected from some sows (stalls, no. = 6; small groups, no. = 6; ESF, no. = 13) using temporary ear catheters (Zanella and Mendl, 1992), and plasma cortisol was measured using a radioimmunoassay technique.

First pregnancy data from the ACTH and DXM tests for sows in the ESF were presented in Mendl *et al.* (1992b). The saliva samples for all three housing conditions were reanalysed because, in the initial analysis of the stall and small group samples, the cortisol levels were very low and there appeared to be no increase after ACTH injection. In the reanalysis presented here, the pattern of change for the ESF sows is the same as in the original analysis and, at all five sample points during the test, there is a significant positive correlation ($P < 0·025$) between the results of the two analyses. In general, the reanalysed cortisol levels are ten times higher, indicating a dilution error in the original analysis, and there is a clear cortisol rise after ACTH injection in stalls and small groups. Although the number of saliva samples successfully analysed for the small group was low during the first pregnancy DXM and ACTH tests, a repeated-measures analysis of variance (ANOVA) was possible on these data.

Test of humoral immunocompetence

Challenge of the immune system was achieved by two 2-ml intramuscular injections of an oil-based atrophic rhinitis vaccine (Intervet, Cambridge, UK) separated by 6 weeks. This vaccine contains two components; a *Bordetella* bacterium and a *Pasteurella* toxin. Blood samples were collected by jugular puncture into silicone coated vacutainer (Becton Dickinson, Meylan, France) tubes. The blood was allowed to clot and settle at room temperature and the serum was pipetted into three aliquots, frozen and stored at −20°C. An enzyme-linked immunosorbent assay technique, based on methods described by Roitt, Brostoff and Male (1989), was developed to assess *Bordetella* antibody concentration and is described in Mendl *et al.* (1992b). The sample titres were expressed as the maximum dilution of sample at which antibody could still be detected. The greater this dilution, the more antibody in the sample.

Blood biochemistry and haematology

Haematology and blood biochemistry can provide information about the levels of particular types of blood cell and metabolites which may be indicative of an animal's immunological and metabolic state. Such information may be useful in assessing the animal's welfare (Broom and Johnson, 1993). For example, is there any evidence that the animal is immunosuppressed? How much energy is it using to deal with the environment? Blood samples collected during the first pregnancy prior to entering the three housing systems and after the first parturition were subjected to a comprehensive haematological and biochemical analysis (assays performed by Central Diagnostic Services, Cambridge University Department of Clinical Veterinary Medicine). Haematology variables analysed included total red blood cell count, packed cell volume, haemoglobin levels, plasma protein levels, mean corpuscular volume, mean cell haemoglobin, mean concentration of haemoglobin in cells, platelet counts, fibrinogen levels, total white blood cell count, and relative proportions of neutrophils, lymphocytes, monocytes and eosinophils from which a heterophil to lymphocyte ratio was calculated. Blood biochemistry variables included levels of urea, glucose, creatinine, total protein, sodium, potassium, chloride, calcium, magnesium, phosphate, alkaline phosphatase, creatine phosphokinase and gamma-glutamyl transferase.

Tail withdrawal tests

These tests of sow responsiveness to external stimuli were similar to the tail flick tests used by Rushen, de Passillé and Schouten (1990) on pigs. One or 2 days prior to the tests, the sows' tails were cleaned and excess hair removed in order to prevent differences in the amounts of hair or dirt covering the tail from influencing the sows' responses. On each test day, each sow's tail was dipped into water at 55°C, and the latency for the sow to remove its tail was recorded. Each sow was tested three times each day, tests being separated from one another by at least 30 min. Sows from the stalls and small-groups were tested between 14.00 and 16.00 h, while sows in the ESF system were tested between 10.00 and 12.00 h. These times coincided with periods when the animals were not expecting food and thus were not in a state of agitation or high activity. Sows were tested on 3 days in total, each test being separated by 3 or 4 days from the previous or next one.

Measures of production

At each parturition, the following measures were made. The number of piglets born alive, dead or mummified, the total number of piglets produced, the sex ratio of the litter, the mean piglet birth weight, and the total weight of piglets born alive. Notes were kept on the number of sows which, for health reasons, had to be removed from each housing system during the study.

Statistical analyses

All statistical analyses were performed using the SPSSX package (SPSS Inc., Chicago, IL.60611, USA). ANOVA was used to compare the behaviour, physiology and reproduction of sows from the three housing systems. Data were transformed as appropriate when the assumption of normality was not fulfilled (Sokal and Rohlf, 1981). Most data were analysed using a one-way ANOVA (SPSSX procedure ONEWAY) with housing type as the between-subjects factor. Multiple comparisons between means were performed using Duncan's multiple range test. Repeated-measures ANOVA (SPSSX procedure MANOVA) was used to analyse the results of the pituitary-adrenal and immune system function tests, with housing as the between-subjects factor and time as the within-subjects factor.

Results

Preliminary results of this comparative study were presented by Mendl, Broom and Zanella (1993a and b). For the sake of clarity and brevity, only statistically significant differences between the housing systems are presented here. Behaviour data showing between-systems comparisons are presented in Figures 1 to 6 and results of ANOVA analyses are given in Table 1. The data from week 1 and week 3 were originally analysed separately but of the 28 significant differences between conditions, 20 were found at 1 and 3 weeks and no difference in week 1 was reversed in week 3. Data from week 1 and week 3 are combined in the following analyses.

Activity time budgets

The instantaneous sample data showed that, on entry to the housing systems at 9 months of age, sows in the small groups were inactive for the least time (Figure 1), and spent most time sitting, standing or moving (Figure 2a). The amount of time that they spent rooting or chewing at straw was greater than that recorded in the ESF system, and was also greater than the amount of time that stall-housed sows spent rooting or chewing at the floor (Figure 2b). Sows in the stalls and small groups spent more time rooting or chewing at pen fittings (bars, troughs) than did sows in the ESF system (Figure 2c). Sows in the ESF

Table 1 *Results of* ANOVAS *on behaviour data from the three housing conditions*

Behaviour	First pregnancy F-ratio	First pregnancy *P*-value	Fourth pregnancy F-ratio	Fourth pregnancy *P*-value
Proportion of activity time budgets	(d.f. 2,62)		(d.f. 2,51)	
Inactive	24·86	<0·001	20·34	<0·001
Sit/stand/move	3·35	0·042	0·38	0·68
Root/chew at floor/straw	36·26	<0·001	19·82	<0·001
Root/chew at pen fittings	26·34	<0·001	32·47	<0·001
Social behaviour	8·75	<0·001	3·94	0·026
Sham chew	13·35	<0·001	9·37	<0·001
Maintenance	12·99	<0·001	10·40	<0·001
Oral stereotypies	(d.f. 2,62)		(d.f. 2,43)	
Sham chew (per h)	32·31	<0·001	12·72	<0·001
Sham chew (s/h)	13·11	<0·001	5·46	0·008
Bar bite (per h)	28·61	<0·001	28·76	<0·001
Bar bite (s/h)	26·25	<0·001	17·00	<0·001
Trough bite (per h)	20·32	<0·001	2·15	0·129
Trough bite (s/h)	17·11	<0·001	1·20	0·312
Total oral stereotypy (per h)	36·27	<0·001	31·57	<0·001
Total oral stereotypy (s/h)	37·07	<0·001	13·29	<0·001
Social behaviour	(d.f. 2,62)		(d.f. 2,50)	
Agonistic interactions	17·30	<0·001	0·48	0·624
Non-agonistic interactions (per h)	3·70	0·03	18·30†	<0·001
% of aggression which is high intensity	22·61‡	<0·001	12·41	<0·001
Fight (per h)	5·55	0·006	nil	nil
Fight (s/h)	2·09	0·132	nil	nil
Belly-nose (per h)	0·99	0·379	4·25	0·02
Belly-nose (s/h)	0·43	0·654	2·65	0·08
% of agonistic interactions in which:	(d.f. 2,58)		(d.f. 2,50)	
pig uses aggression	15·60	<0·001	13·04	<0·001
pig actively avoids	29·10	<0·001	40·10	<0·001
a clear result occurs	85·55	<0·001	23·80	<0·001
escalation occurs	1·71	0·190	47·35	<0·001

† d.f. 2,43.
‡ d.f. 2,58.

house were involved in most social behaviour (Figure 2d), while sows in the stalls spent most time sham chewing (Figure 2e) and performing maintenance behaviour (Figure 2f). Increased drinking and drinker related behaviour in stall-housed sows accounted for this last result and made up 0·86 of the maintenance behaviour performed by these animals. This behaviour, much of which was repetitive, has been classified as a stereotypy by others (e.g. Terlouw, Lawrence and Ilius, 1991). By the fourth pregnancy, the activity of the stall-housed sows had increased dramatically and they were now inactive for the least time, with sows in the ESF

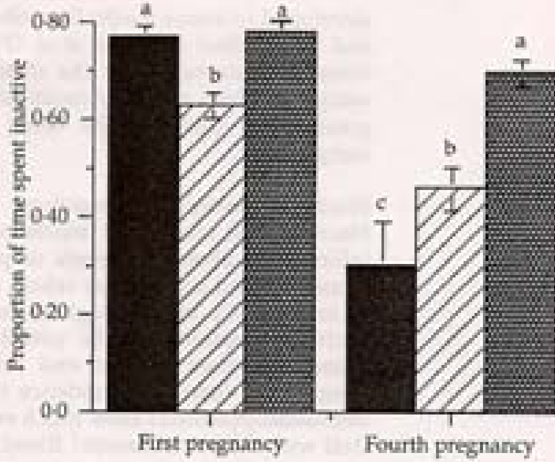

Figure 1 Mean proportion of observation time spent inactive by sows during the first and fourth pregnancy in the stall house (■), small groups (▨), and ESF house (▩). Error bars denote one s.e. If letters above columns are different, $P < 0·05$.

system being inactive for the most time (Figure 1). Stall-housed sows also showed the highest levels of social behaviour (together with sows in the ESF house, Figure 2d) and maintenance behaviour (Figure 2f), and they also spent most time rooting or chewing at pen fittings (Figure 2c) and sham chewing (Figure 2e). Levels of these last three behaviour patterns were far higher than those performed by the same stall-housed sows during the first pregnancy. Once again, the high level of maintenance behaviour seen in stall-housed sows was primarily due to excessive drinking and drinker related behaviour which made up 0·91 of maintenance activities. Hence 'drinking' proportionately occupied over 0·10 of time in stall-housed sows but 0·02 or less in group-housed sows. Rooting or chewing at pen fittings was sometimes stereotyped and occupied over 0·20 of time in stall-housed sows but 0·02 or less in the group-housed sows. The amount of time that sows in the small groups spent rooting or chewing at straw continued to be greater than that seen in the ESF system, or in the stalls (Figure 2b).

Oral stereotypies

Focal observations of three types of oral stereotypy showed that stall-housed sows performed most sham-chewing (Figures 3a and b) and bar-biting (Figures 3c and d) during the first pregnancy, both in terms of frequency and duration, while trough biting, whose frequency and duration was relatively low, was performed most by sows in their first pregnancy in the small groups (Figures 3e and f). In total, stall-housed sows in their first pregnancy spent

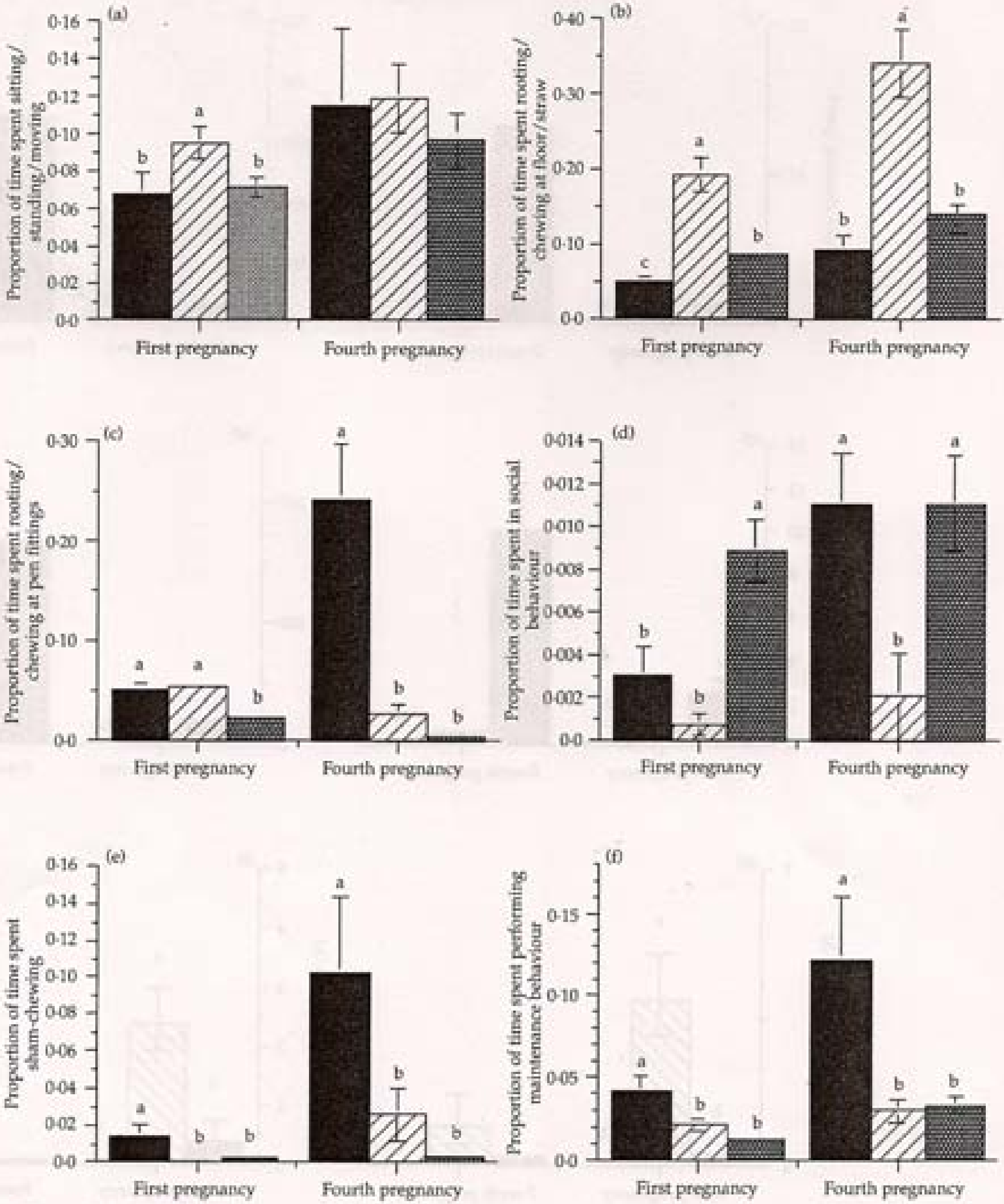

Figure 2 Mean proportion of observation time spent (a) sitting, standing or moving, (b) rooting or chewing at straw/floor, (c) rooting or chewing at pen fittings, (d) performing social behaviour, (e) sham chewing, and (f) performing maintenance behaviour by sows during the first and fourth pregnancies. Stall house (■), small groups (▨), and ESF house (▩). Error bars denote one s.e. If letters above columns are different, $P < 0.05$.

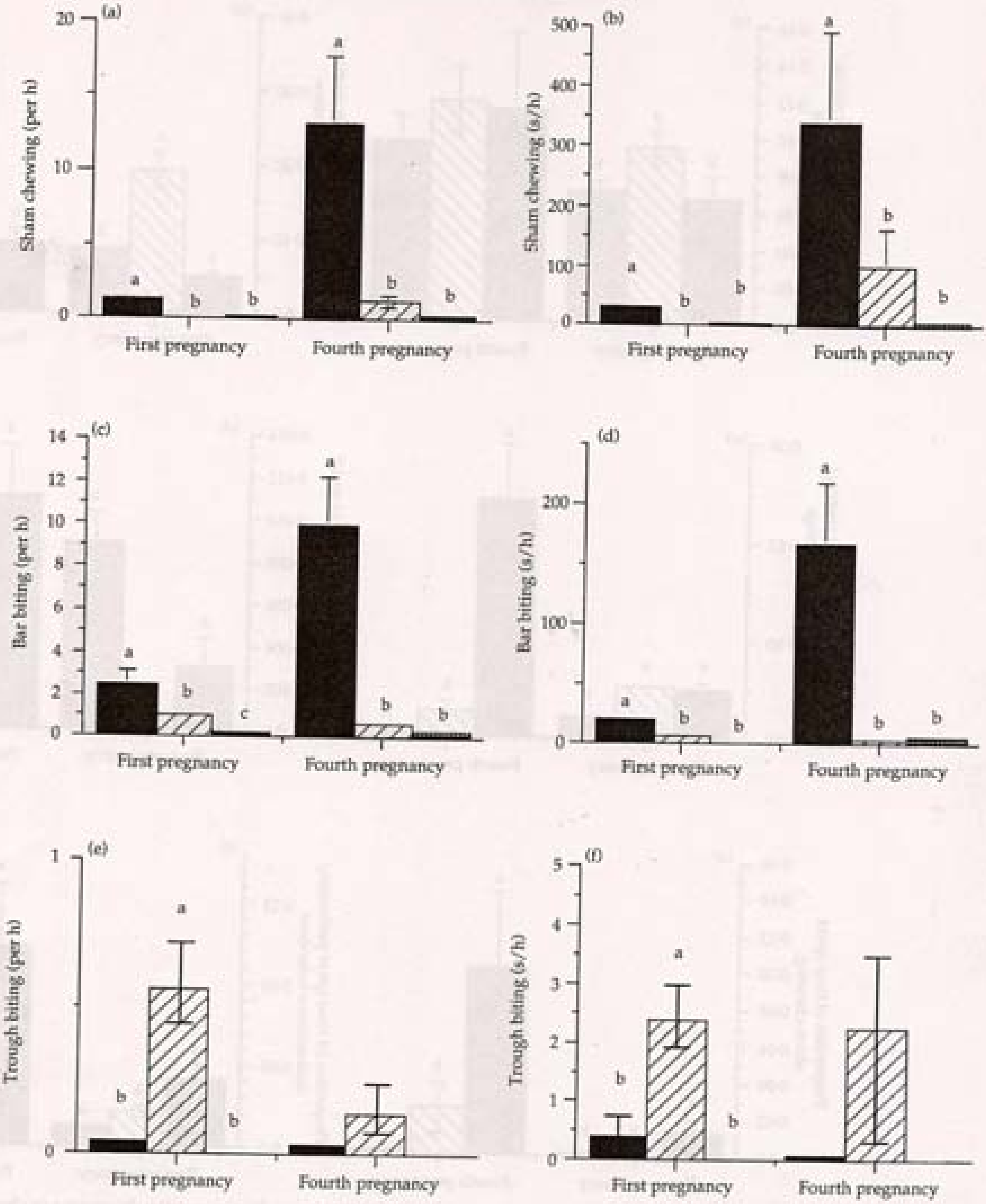

Figure 3 Mean frequency per h of performance of (a) sham chewing, (c) bar biting, and (e) trough biting, and mean duration per h spent (b) sham chewing, (d) bar biting, and (f) trough biting by sows during the first and fourth pregnancies. Stall house (■), small groups (▨), and ESF house (□). Error bars denote one s.e. If letters above columns are different, $P < 0.05$.

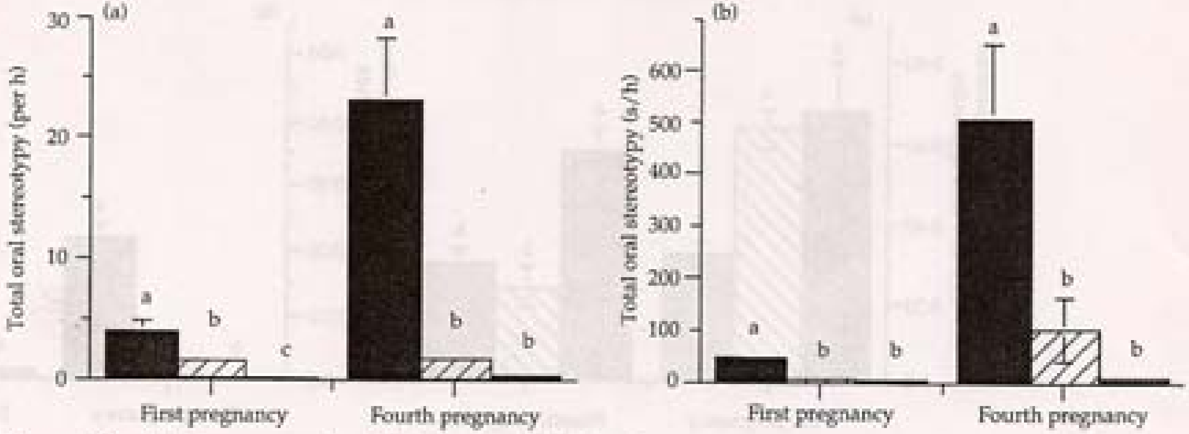

Figure 4 Mean (a) frequency per h and (b) duration per h of total stereotypy performed by sows during the first and fourth pregnancies. Stall house (■), small groups (▨), and ESF house (▦). Error bars denote one s.e. If letters above columns are different, $P < 0{\cdot}05$.

most time performing these behaviour patterns (Figure 4). During the fourth pregnancy stall-housed sows continued to perform the most sham-chewing (Figures 3a and b) and bar-biting (Fugures 3c and d). The levels of each of these behaviour patterns and of total stereotypy (Figure 4) were far higher than those seen during the first pregnancy; for example, bar-biting and sham-chewing by stall-housed sows occupied means of 18 and 27 s/h in the first pregnancy but 166 and 340 s/h in the fourth. Total stereotypy levels were highest in stall-housed sows, and reached a mean of 506 s/h (0·14 of time) in the fourth pregnancy (Figure 4). This does not include the time spent performing excessive drinking behaviour or rooting and chewing at pen fittings which could also be argued to be stereotypic (see previous section). It should be emphasized that these are mean values and that some sows spent considerably longer than these mean times performing stereotypies. One sow spent 1567 s/h (0·43 of time) performing stereotypies.

Social behaviour

During the first pregnancy, stall-housed sows were involved in the fewest agonistic interactions and the most non-agonistic interactions (Figure 5). Sows in the ESF system used aggression least (Figure 6a) and active avoidance most (Figure 6b) during these encounters. They also had the highest proportion of decisive agonistic interactions (Figure 6c). Stall-

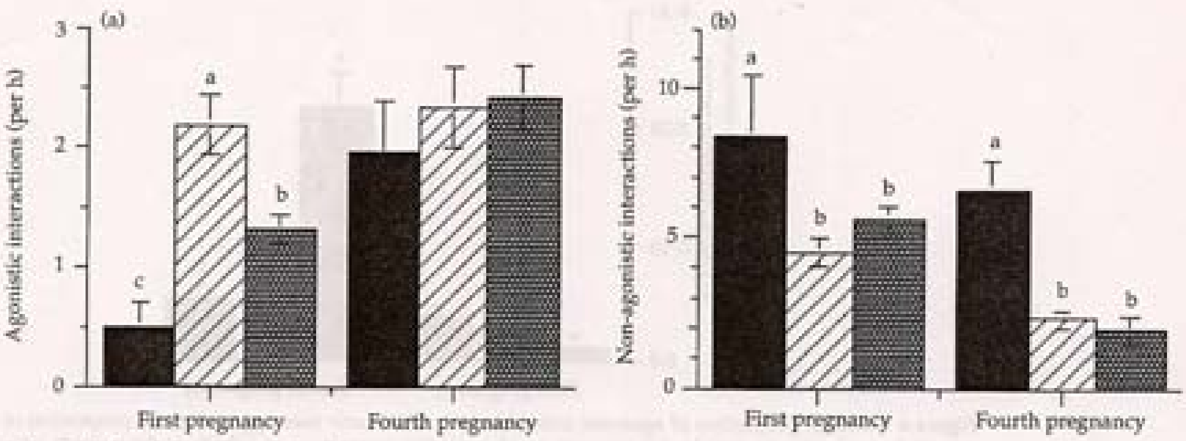

Figure 5 Mean frequency per h of (a) agonistic interactions and (b) non-agonistic interactions in which sows were involved during the first and fourth pregnancies. Stall house (■), small groups (▨), and ESF house (▦). Error bars denote one s.e. If letters above columns are different, $P < 0{\cdot}05$.

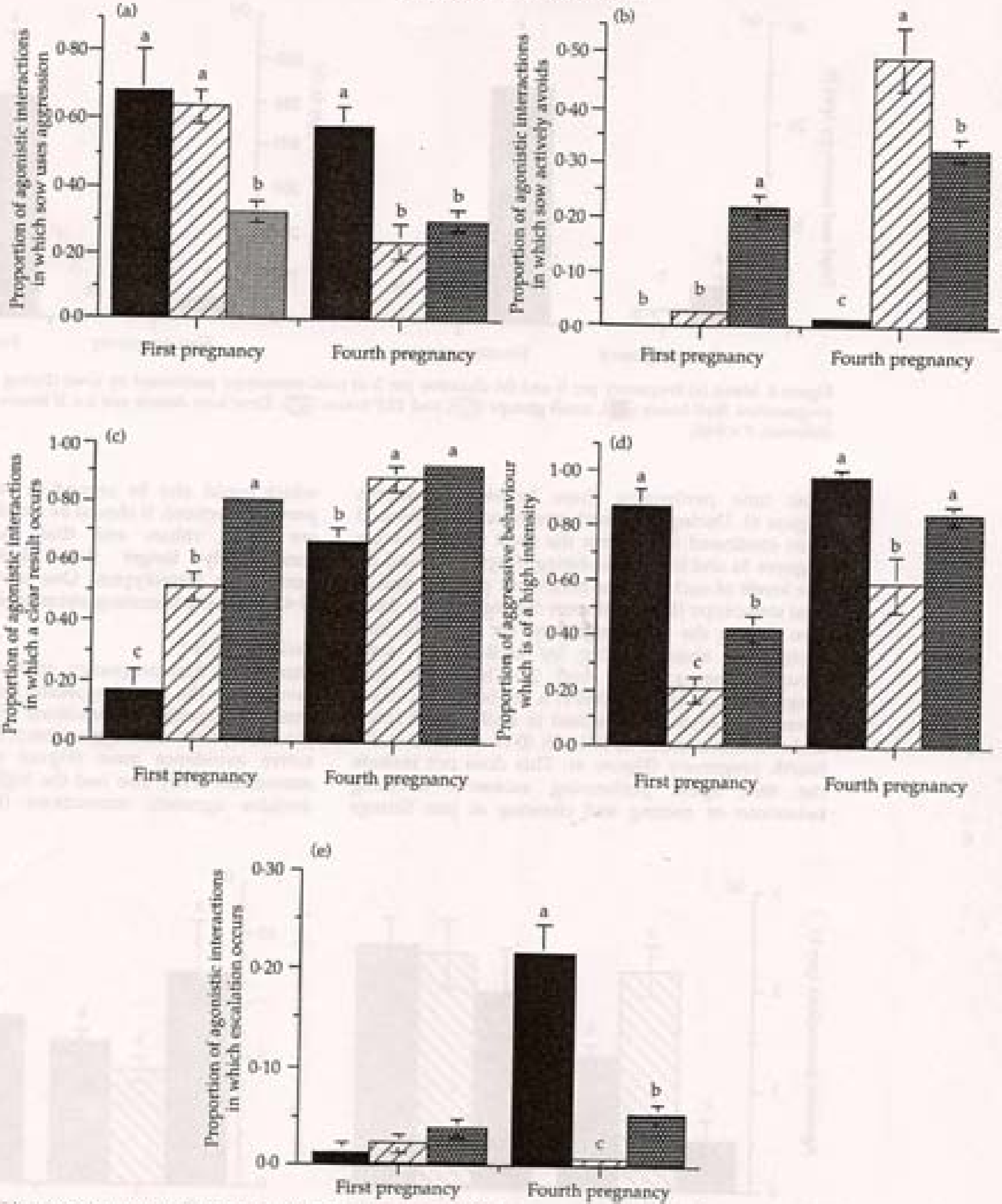

Figure 6 Mean (a) proportion of agonistic interactions in which sow uses aggression, (b) proportion of agonistic interactions in which sow actively avoids, (c) proportion of agonistic interaction in which a clear result occurs, (d) proportion of aggressive behaviour which is of high intensity, and (e) proportion of agonistic interaction in which escalation occurs during the first and fourth pregnancies: stall house (■), small groups (▨), and ESF house (▤), error bars denote one s.e. If letters above columns are different, $P < 0{\cdot}05$.

housed sows, on the other hand, were least likely to have agonistic encounters with clear outcomes (Figure 6c), and they used high intensity aggressive behaviour (bites through the bars by these sows as compared with bites plus chases by group-housed sows) most readily (Figure 6d). During the fourth pregnancy, stall-housed sows continued to show the highest levels of non-agonistic behaviour, but they now performed as much agonistic behaviour as sows housed socially (Figure 5). During these agonistic interactions, they were considerably more likely to use aggressive behaviour (Figure 6a), used the lowest levels of active avoidance behaviour (Figure 6b), had the fewest clear outcomes (Figure 6c), and escalated the interaction most (Figure 6e). Their aggressive behaviour, together with that of sows in the ESF system, contained the highest proportion of high intensity aggression (Figure 6d). Fighting occurred only in the ESF-system sows during the first pregnancy. The mean frequency was 0·04 (s.e. 0·01) per h ($F = 5·55$, $P = 0·0006$). No fighting was observed during the fourth pregnancy. Belly-nosing behaviour was observed to occur most frequently in the small groups (fourth pregnancy: small group: 4·1 (s.e. 2·8) s/h, ESF: 0·3 (s.e. 0·2) s/h, $F = 4·25$, $P = 0·02$).

Pituitary-adrenal function
Sows in the three housing systems did not differ in their salivary cortisol responses to the DXM or ACTH injections during the first pregnancy (Figure 7a). There was no significant difference between sows from the three housing systems in their plasma cortisol responses to the DXM test or the ACTH test during the fourth pregnancy (Figure 7b). However, the salivary cortisol data, which were based on a slightly larger sample size suggested that sows in the ESF system showed a less marked response to DXM ($F = 4·12$, d.f. 2,27, $P = 0·027$) than sows in the other two systems (Figure 7c).

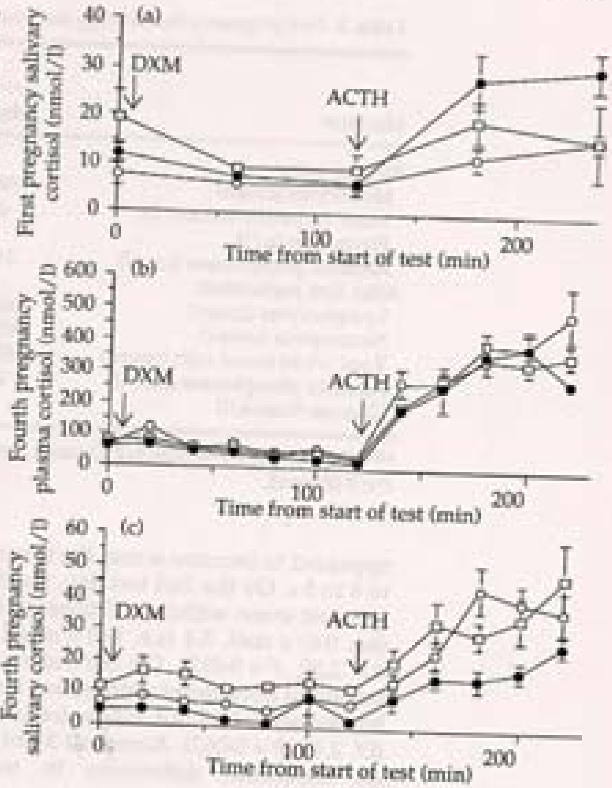

Figure 7 Mean levels of (a) salivary cortisol during first pregnancy test of pituitary adrenal function, and of (b) plasma and (c) salivary cortisol during fourth pregnancy test of pituitary adrenal function for sows from the stall house (●), small groups (○), and ESF house (□). Error bars denote one s.e., DXM-dexamethasone, ACTH-adrenocorticotrophic hormone.

Humoral immunocompetence
No differences between sows in their first pregnancy from the three housing systems in antibody response to the *Bordetella* component of the atrophic rhinitis vaccine were observed. The antibody titre increased, as expected, from a baseline level of zero to *ca.* 1000 after 6 weeks and *ca.* 3000 after a further 6 weeks, by which time the sow was lactating.

Haematology and blood biochemistry
Few differences in haematology and blood biochemistry were found, and there were no more differences found after the sows had entered the systems than there were before. Data and significant results are presented in Table 2. Prior to entry, there were differences in the levels of fibrinogen, monocytes, alkaline phosphatase and mean corpuscular volume. After the first parturition, all white blood cell counts were in the normal clinical range but animals in the ESF-system sows had the highest lymphocyte and total white blood cell count while those in the small group had the lowest neutrophil count. There were no differences in the heterophil to lymphocyte ratio. The alkaline phosphatase levels were lower after the first parturition, an expected change with age, but the level was highest in the ESF system. Glucose levels were highest in stall-housed sows and lowest in the small group.

Tail withdrawal tests
Sows' tail withdrawal latencies were highly positively correlated within the three tests performed on each test day. Similarly, the mean tail withdrawal latencies for each sow on each day were positively correlated (Spearman rank correlations, $P < 0·001$) across all three test days. Tail withdrawal latencies

Table 2 First pregnancy haematology and biochemistry measures and analyses

Measure	Stall		Small group		ESF		ANOVA		
	Mean	s.e.	Mean	s.e.	Mean	s.e.	F-ratio	d.f.	*P*-value
Prior to entry									
Monocytes (count)	593^{b}	129	1920^{a}	1506	579^{b}	45	3·97	2,51	0·025
Mean corpuscle volume (fl)	63·3^{a}	0·74	61·6^{ab}	1·2	61·0^{b}	0·47	3·21	2,53	0·049
Fibrinogen (g/l)	4·1^{a}	0·51	2·0^{b}	0·45	3·3^{ab}	0·21	4·02	2,53	0·024
Alkaline phosphatase (i.u./l)	146·0^{b}	6·3	157·0^{ab}	15·5	170·8^{a}	5·1	3·5	2,50	0·038
After first parturition									
Lymphocytes (count)	4618^{b}	294	4398^{b}	596	5998^{a}	335	4·64	2,56	0·014
Neutrophils (count)	7015^{b}	364	4908^{b}	619	7774^{a}	502	6·74	2,56	0·002
Total white blood cells (count)	12653^{b}	557	10287^{b}	1226	15212^{a}	536	11·08	2,56	<0·001
Alkaline phosphatase (i.u./l)	72·5^{b}	8·2	67·7^{b}	6·9	90·6^{a}	4·2	5·04	2,56	0·009
Glucose (mmol/l)	5·31^{a}	0·23	4·1^{c}	0·13	4·63^{b}	0·16	7·92	2,56	0·001

^{a,b,c} Denote results of post-hoc Duncan multiple range tests. Housing systems with different letters are significantly different at $P < 0·05$ level.

appeared to increase across the three test days from 3 to 4 to 5 s. On the 2nd test day, the ESF sows had the quickest mean withdrawal times (3·4 (s.e. 0·4) s *v.* 4·6 (s.e. 0·6) s stall, 5·4 (s.e. 1·0) s small group, F = 4·84, d.f. 2,50, *P* = 0·012). On the 3rd test day, ESF sows tended to have faster withdrawal latencies than stall-housed sows (4·0 (s.e. 0·4) *v.* 6·4 (s.e. 1·4) s, F = 2·96, d.f. 2,46, *P* = 0·062). Across all 3 test days, there were no significant differences in mean withdrawal latencies.

Sow weight and reproduction

Data on sow weights are given in Figure 8. One or 2 days prior to entry into the housing systems during the first pregnancy, sows that were assigned to the stall and ESF houses weighed more than those assigned to the small groups (F = 6·12, d.f. 2,63, P = 0,04). After 1 month in the housing systems, the stall-housed sows were still heaviest but those in the ESF system were now no heavier than those in the small groups (F = 6·03, d.f. 2,60, *P* = 0·004). Consequently, growth rate during this 1st month was lowest in the ESF system (F = 8·97, d.f. 2,60, *P* = 0·0004). Just before the first parturition, stall-housed sows were still heavier than those housed socially (F = 3·15, d.f. 2,61, *P* = 0·05), but after separation from their first litters they tended to be heavier than sows from the small groups only (F = 2·93, d.f. 2,61, *P* = 0·061). At the end of the fourth pregnancy sows housed socially were heavier than those housed in stalls both before parturition (F = 3·98, d.f. 2,61, *P* = 0·024) and after separation from their fourth litters (F = 4·39, d.f. 2,57, *P* = 0·017). The weight gain from pre-farrowing in pregnancy 1 to pre-farrowing at pregnancy 4 was greater in ESF sows (49·7 kg) and small group sows (53·6 kg) than in stall-housed sows (22·6 kg, F = 9·97, d.f. 2,58, *P* = 0·0002). Post-farrowing weight gains during this period were also least in stall-housed sows (F = 12·7, d.f. 2,57, *P* = 0·0001).

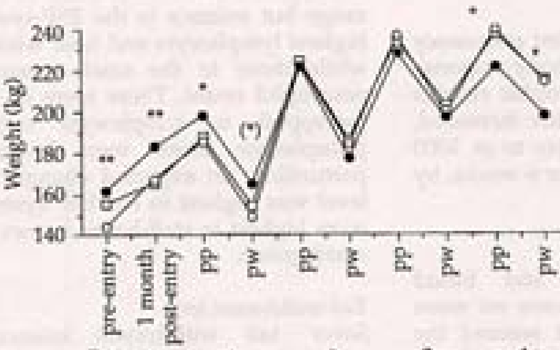

Figure 8 Mean body weight of sows at key points (pp = pre-partum; pw = post weaning) during the four pregnancies. Stall house (●), small groups (○), and ESF house (□). *$P < 0·05$; **$P < 0·01$; (*)$P < 0·1$.

Few reproductive differences were found. At the end of the second pregnancy, stall-housed sows gave birth to more live-born piglets (mean = 12·6) than sows housed socially (small group mean = 8·9, ESF mean = 9·9; F = 3·81, d.f. 2,61, *P* = 0·028), and sows from the small groups produced the largest numbers of mummified piglets (stall mean = 0, small group mean = 0·6, ESF mean = 0·06; F = 6·78, d.f. 2,61, *P* = 0·002). There were no significant differences over the four parturitions combined.

Immediately following introduction to the housing systems, one sow from the ESF system and one from the stall house had to be removed due to upper leg problems. Over the course of the study, two sows had to be removed from the stall house as they had developed sores on their legs and were experiencing problems standing up and lying down. One stall-housed sow died due to an acute urino-genital infection. No sows were removed from the small groups, but in the ESF house one sow had to be removed due to upper leg problems.

Discussion

The scientific assessment of animal welfare is a complicated process (Rushen, 1991; Broom and Johnson, 1993; Mason and Mendl, 1993). Various measures of an animal's response to a particular situation can be made and conclusions can be drawn, based on these measures, as to how difficult the animal finds the situation. Other measures, such as those of disease incidence or reproductive output, can give further information about the effects of the situation on the animal. However, interpretation of behavioural and physiological measures in terms of animal welfare is not always straightforward (Barnett and Hemsworth, 1990; Rushen, 1991; Mason and Mendl, 1993), and there is debate about the relative importance of different measures (Dawkins, 1990; Broom, 1991; Duncan and Petherick, 1991; Mendl, 1991). This state of affairs is to be expected in a young science and it calls for at least three complementary approaches: in depth studies of the usefulness of particular welfare indicators, studies of inter-relationships amongst measures and studies of welfare problems which use a wide variety of measures simultaneously. The present study was designed to fit into the third category and, hence, relies on current knowledge of a variety of welfare indicators for an assessment of the welfare consequences of the sow housing systems studied. It also provides some information about inter-relationships amongst measures, but these are the subject of separate papers (e.g. Mendl *et al.*, 1992b). Where several measures of welfare are used, they will often have different levels of sensitivity and may reflect responses or effects which are present in some individuals but not in others. Therefore, some measures may fail to show up any differences between animals in different conditions. However, any single indicator can, on its own, provide evidence that welfare is poor.

Comparison of group-housed and stall-housed sows

Each of these conditions of housing was designed to be a very good example of its kind. Several measures suggest that stall-housed animals found the conditions more difficult than those housed in groups. During both first and fourth pregnancies, they spent much more time performing stereotypies than group-housed sows. In the fourth pregnancy the stall-housed sows spent a mean of proportionately 0·14 of time on obvious stereotypies, >0·10 'drinking' and >0·20 rooting or chewing at pen fittings. The total times, expressed as proportions of observation time, spent on all of these largely stereotyped activities were 0·50 (s.e. 0·092) for stall-housed sows, 0·08 (s.e. 0·018) for sows in small groups and 0·04 (s.e. 0·007) for sows with an electronic feeder. Although there is still debate as to the significance of stereotypies in welfare terms (Mason, 1991), a considerable body of evidence indicates that they often develop in situations where the animal is frustrated in that its needs cannot be fulfilled (Mason, 1991; Broom and Johnson, 1993). This would suggest that the stall-housed sows encountered such frustrating situations more often than those housed in groups, due possibly to their inability to satisfy motivation to move, forage and express other forms of behaviour, and due to frustration caused by unresolved agonistic encounters with neighbours (see below).

It is clear from work such as that of Lawrence and Terlouw (1993) that feeding motivation can have a rôle in the development of sow stereotypies. The proportion of roughage in the diet or the time taken to consume food also has an effect on stereotypies since Broom and Potter (1984) reported that feeding extra oat hulls resulted in less activity and less bar-biting but more sham-chewing in stall-housed sows and Brouns, Edwards and English (1994) found that feeding extra sugar-beet pulp resulted in less sham-chewing and bar-biting in group-housed sows. In the study reported here, however, the sows in each of the conditions received the same concentrate diet and although some straw was eaten by group-housed sows and none by sows in stalls, it is most unlikely that differences in food availability account for the large differences between stall and group-housed animals in stereotypy incidence.

In stalls there was a substantial increase in the duration of stereotypies between the first and the fourth parity. Stolba, Baker and Wood-Gush (1983) and Cronin and Wiepkema (1984) also reported that the time spent performing stereotypies increased substantially with time spent in stalls. In the group-housing systems, however, changes across time were much less pronounced. Straw was observed to be eaten by group-housed sows and the provision of straw or similar roughage is clearly desirable for sows given a restricted concentrate diet. The stall-housed sows did not have straw at all during pregnancy but they showed a substantial increase in the performance of stereotypies between the first 3 weeks of the first parity and the fourth parity. Hence it is unlikely that changes in the ratio of food availability to food requirement during this study accounted for much of the difference in stereotypy incidence. The stall-housing environment seems to have promoted the development of stereotypies much more strongly than did group-housing.

The behaviour of stall-housed sows has previously been considered to be of two kinds, some of the sows being high stereotypers whilst others show low activity and responsiveness (Broom, 1987). Most of the stall-housed sows in this study came into the first category. Our tail withdrawal response data do not allow us to say that any of these high stereotyping sows had developed an unresponsive state induced by prolonged confinement (Broom, 1987; Wemelsfelder, 1993).

Further evidence of problems for stall-housed sows comes from the fact that they experienced undecided agonistic interactions up to three times as often as group-housed sows, were scarcely able to use active avoidance behaviour, and escalated agonistic interactions most often. This was particularly evident in the fourth pregnancy. Barnett, Hemsworth and Winfield (1987b) suggest that this apparent inability to resolve agonistic interactions is likely to be a cause of stress.

Although stall-housed sows were heavier prior to allocation to housing conditions and during the first pregnancy, it is apparent that their body weight, relative to those housed in groups, decreased across time such that they were considerably lighter by the fourth pregnancy. In fact, their mean pre-parturition weight at the fourth pregnancy was less than that at the third pregnancy, while this was not the case for group-housed sows. All sows were given the same diet during the study, although the group-housed sows had the opportunity to eat straw, and stall-housed sows received supplementary heating in cold weather, so the question arises as to why these differences in body weight emerged. One possible explanation is that the low amount of time spent inactive by stall-housed sows during the fourth pregnancy, and the large amount of time spent performing energetically costly stereotypies (Cronin, 1985) contributed to their relatively low weight.

The high incidence of health problems requiring stall-housed sows to be removed from the system (three out of 12 sows, including one death; 0·25) compared with the incidence in the small group (0·0) and ESF system (0·05), also suggests that the stall house caused more problems than the other systems. The sample size is small, but the observations are mentioned because they add to other evidence suggesting that stall-housed sows are particularly susceptible to sores on legs and urino-genital infections, while sows in the ESF house appeared to suffer more upper leg problems.

The clearest indicators of welfare problems for sows in the group-housing conditions were the high levels of aggression during the first pregnancy. The mean frequency of agonistic interactions was higher in the group housing systems than in the stalls and, although the proportion of such encounters in which overt aggression occurred was higher in the stalls, the overall frequency of aggression was higher in the group-housing. Fights were recorded only during the first pregnancy in the ESF system, especially in the period immediately following introduction. This evidence supports the findings reported elsewhere that severe problems for individuals can occur soon after mixing (Hunter *et al.*, 1988). Agonistic behaviour can be stressful to the individuals concerned, and data from the ESF system showed that the individuals most affected were those who behaved aggressively, but lost most agonistic encounters. These sows exhibited particularly high levels of adrenocortical activity (Mendl *et al.*, 1992b). In addition, growth rate during the 1st month was lower in the ESF system than in the other two systems. Socially induced stress may have been partly responsible for this finding, perhaps through the catabolic actions of elevated glucocorticoid activity. These aggression-related problems were temporary however for, during the fourth pregnancy, no fighting was recorded, the levels of agonistic interactions in the stall and group-houses were similar and it was stall-housed sows who used overt aggression and escalated these encounters most often. Sows returning to the groups after periods in farrowing and service accommodation were sometimes involved in agonistic interactions but levels of overt aggression were lower than in the stall house.

Many of the other measures used showed no differences, or no consistent differences between stall-housed and group-housed animals. There were no clear differences in response to the ACTH challenge tests. Likewise, the measures of immunocompetence showed no differences between the housing conditions in the amount of antibody produced following antigen challenge. Neither was there any clear difference in the haematology, blood biochemistry or in reproductive output. There was a greater mean litter size in stall-housed sows during the second parity but overall no differences in reproductive output were observed.

Comparison of sows housed in small groups or in an electronic sow feeder system

A major welfare problem in group-housing systems is aggression which is often localized around food. The behaviour data collected here indicated some differences in the use of aggression in the two group housing systems during the first pregnancy. ESF sows were involved in higher intensity but more decisive interactions, while sows in the small groups were involved in more agonistic interactions in total, a lower proportion of which resulted in clear outcomes. Perhaps the smaller pen area available to the sows in their first pregnancy in small groups prevented the occurrence of clear avoidance behaviour and more decisive agonistic interactions. As mentioned above, unresolved agonistic interactions may be a cause of socially induced stress (Barnett *et al.*, 1987b), but high intensity aggression and fights, which were only seen in the ESF system, may cause immediate and severe injuries. It is difficult to evaluate which is worse for the sows involved. There were no differences between small group and ESF sows in their first pregnancy in response to the tests of pituitary-adrenal function and immunocompetence, so these data do not help to resolve this issue.

Abnormal behaviour during the first pregnancy, although much lower than in stalls, was higher in the sows in small groups than in the ESF in that there was more total oral stereotypy and more rooting and chewing pen fittings, and bar and trough biting. The sows in the small groups had less total space available to them than did the sows in the ESF and perhaps also experienced frustration due to a greater proportion of their agonistic interactions being unresolved. Both of these factors are likely to account for some of the differences in abnormal behaviour. In addition, the sows in the small group ate from a trough with bars in front of it, so when the food ration had been consumed they were easily able to redirect any feeding motivation to the food trough and bars, and thus to show oral stereotypies. Trough and pen design offered less opportunity for sows in the ESF system to bar-bite.

Counts of lymphocytes, neutrophils and total white blood cells were higher in the ESF sows. Alkaline phosphatase dropped after residence in the housing systems but remained higher in the ESF sows during the first pregnancy. However, the interpretation of these results is not clear.

There were fewer differences between the sows in the small groups and sows in the ESF system after the first pregnancy. Sows in the ESF were inactive for longer, spent more time interacting socially and less time rooting or chewing at the floor or straw. Few differences in agonistic interactions were observed and, in general, the use of aggression during agonistic encounters had fallen relative to the first pregnancy. The occurrence of active avoidance behaviour was higher in the fourth pregnancy, and proportionately 0·90 of agonistic interactions in both systems had clear outcomes. In addition, no fights were observed in either housing system. Thus, the general picture that emerges is of increasing social stability with time in both systems.

In terms of abnormal behaviour, there were no differences in oral stereotypies between sows housed in small groups and in the ESF during the fourth pregnancy, although belly nosing behaviour occurred at higher levels in the small groups due to a few individuals performing large amounts of this behaviour. There were also no differences in adrenal function tests in the fourth parity but tail withdrawal latency was less in the ESF sows on one of the three testing days. In general, therefore, the social groups of sows appeared to be more settled in the fourth pregnancy and there were few obvious welfare problems for them at this stage.

Conclusions

The largest amount of information about the welfare of the sows was obtained from the measures of behaviour, particularly measures of abnormal behaviour and aggression. Some of these measures could be related to both adrenal function and production (Mendl *et al.*, 1992b). Measures of health problems requiring sows to be removed from a housing system also provided useful information. In general, measures of physiology picked out few differences between housing conditions. The absence of differences amongst the conditions in the measures of immunocompetence is not too surprising because the test used was relatively insensitive (e.g. Okimura, Ogawa, Yamauchi and Sasaki, 1986). Similarly, most of the haematology and blood biochemistry measures are likely to reflect only larger differences between conditions than were evident in this study. The analysis reported here evaluated the relationships between different welfare indicators at a crude level. Namely, by looking for clusters of responses within each experimental treatment. A more finely tuned analysis of within-individual associations of behavioural and physiological responses is, however, beyond the scope of the present report (see Zanella, Broom and Hunter, 1991; Mendl *et al.*, 1992b).

This study has the advantage that the genetic strain, the early experience of the sows, the buildings, the food and care by staff were carefully matched. However, it also has the disadvantage that only one example of each type of rearing condition was studied. Hence, we have been careful to present conclusions about the conditions which we used. An evaluation of the measures used in this study suggests that, on balance for these three sets of sows, there were more welfare problems for sows housed in the stalls than in either group-housing condition. The differences were present in the first pregnancy, when there were also some problems in the group-housing systems, but they were particularly evident after four pregnancies in the housing systems when stereotyping incidence and escalated aggression were much higher in the stalls. This finding emphasizes the importance of long-term evaluations of welfare in housing systems.

The success of both group-housing systems used in this study must be partly attributable to the high social stability in the groups. In the lifetime of a particular sow in a large group the period shortly after it is introduced to the group is likely to be the most difficult, as it was for the sows in the ESF in our study. We are currently investigating the best way to carry out such introductions. Our data did not allow a simple conclusion to be drawn about welfare in the small groups as opposed to the ESF. The worst problems in both group-housing systems occurred at initial mixing and some further problems occurred at subsequent mixing of sows returning after farrowing. The smaller amount of pen space available to sows in the small groups may have slowed down the speed at which they established a stable social organization by preventing the occurrence of active avoidance behaviour and decisive outcomes of agonistic interactions. A total space available larger than 5 × 2·2 m would seem desirable for group-housed sows.

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