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The effect of feeding a high fibre diet on the welfare of sows housed in large dynamic groups

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Abstract

This study assessed the effect of increasing fibre levels in the concentrate ration on the welfare of sows housed in a large dynamic group. One hundred and twelve Large White × Landrace sows were allocated to one of two treatments over six replicates. Treatments were as follows: (i) High Fibre diet (~15% CF [Crude Fibre]), and (ii) Control diet (~5% CF). Treatments were applied to two separate dynamic groups each containing 33 (± 3) sows in a cross-over design, after three replicates the treatments were switched between the groups. Approximately nine sows were replaced in each of these groups at 3-week intervals (each replacement constituting a replicate of the study). Sows on the high fibre diet spent a greater percentage of time lying (High Fibre: 43.8, Control: 28.0, SEM 3.25%), while sows on the control diet spent more time sham chewing (High Fibre: 7.2, Control: 28.8, SEM 1.55%). Sows newly introduced to the group on the high fibre treatment spent proportionally more time in the kennel areas compared to newly introduced sows in the control treatment (High Fibre: 0.893, Control: 0.788, SEM 5.10). In general, aggression occurred at a very low frequency and overall levels did not differ between treatments (High Fibre: 0.005, Control: 0.003, SEM 0.0007 [occurrences per min]). However, sows in the control treatment performed head thrusting (High Fibre: 0.02, Control: 0.00, SEM 0.001 [occurrences per min]), and biting behaviour (High Fibre: 0.02, Control: 0.01, SEM 0.002 [occurrences per min]) more frequently than sows on the high fibre diet. There was no effect of treatment on physiological parameters such as plasma cortisol (High Fibre: 1.34, Control: 1.44, SEM 0.114 ng ml^{-1}) or haptoglobin levels (High Fibre: 0.73, Control: 0.64, SEM 0.080 mg ml^{-1}). In summary, provision of a high fibre diet had a positive effect on the welfare of group-housed dry sows. Sows on the high fibre treatment spent more time resting in the kennel areas, less time performing stereotypic behaviours and showed a reduction in some aggressive behaviours relative to sows fed the control diet.

Keywords: *animal welfare, behaviour, dynamic group, high fibre diets, physiological measures, sows*

Introduction

Recent amendments to European Union pig welfare legislation state that pregnant sows and gilts must be provided with sufficient amounts of bulky or high fibre diets and high energy food to satisfy hunger and the motivation to chew (Council Directive 2001/88/EC 2001). These changes arose because pregnant sows are typically restricted to 60% of their *ad libitum* intake in order to optimise reproductive performance (Ramonet *et al* 2000a). However, this leaves them hungry which can lead to increased aggression (Jensen *et al* 2000), higher levels of physical activity (De Leeuw *et al* 2005) and the development of stereotypies (Lawrence & Terlouw 1993).

Previous research has shown that increasing the dietary fibre content of pregnant sow diets through the use of sugarbeet pulp is highly effective in improving sow welfare (Brouns *et al* 1994; Ramonet *et al* 2000b). This is because sugarbeet pulp contains high levels of soluble fibre which is more readily digested than fibre provided from more 'insoluble' sources (Serena *et al* 2007). However, sugarbeet pulp has also been found to significantly lengthen the time taken to complete feeding relative to control diets (Brouns *et al* 1994). This may not suit commercial systems where large groups of sows are fed sequentially, and where all sows must complete a feeding cycle within a specified timeframe. Therefore, it is important to assess the effectiveness of other fibre sources in improving the welfare of pregnant sows in large group systems.

Large group systems for sows are often operated as dynamic groups, where sows which are due to farrow are removed from the group and replaced by sows which have just been mated. This type of system is associated with greater welfare problems than when sows are housed in small, static groups, mainly because of the larger group size (Mendl *et al* 1993), and the fact that the group is in a state of continuous social flux (Simmins 1993). This system can lead to particular problems for newly introduced animals to the group, which are often subjected to high levels of aggression (Moore *et al* 1993; O'Connell *et al* 2003) and often have difficulty gaining access to prioritised resources (O'Connell *et al* 2002). Therefore, the influence of provision of high fibre diets on the welfare of these animals is of particular importance.

The aim of this study was to assess the effect of providing increased levels of dietary fibre (through use of soya hulls and sugarbeet pulp) on the welfare of sows (in particular, newly introduced sows) in a large dynamic group housed in a split-yard system. Welfare was assessed using a multi-disciplinary approach that included recording behaviour, injury levels and physiological parameters.

Materials and methods

The effect of increasing fibre levels in the concentrate ration offered to sows in large dynamic groups was assessed using two isoenergetic treatments and six replicates. Treatments were as follows: C — Control diet formulated to contain 5.0% Crude Fibre and 13.4 MJ kg^{-1} DM Digestible Energy (DE) and H — High fibre diet formulated to contain 15.7% Crude Fibre and 10.3 MJ kg^{-1} DM DE.

Animals, housing and management

One hundred and twelve Large White × Landrace sows were used in this experiment. The sows used were multiparous animals with an average parity of 5 (± 3). The parity number was balanced across both treatments. Weaning occurred when the piglets were 28 (± 3) days old, the sows were then weighed and mixed into groups of four. These groups were housed in service pens (5.0 × 2.4 m; length × breadth) that consisted of four voluntary cubicles (2.0 × 0.6 m), a slatted exercise area (1.5 × 2.4 m) and a kennel area with a solid floor (1.5 × 2.4 m). Sows were artificially inseminated 5 days after introduction to the service pen and then transferred to the large group 28 days after insemination.

Approximately 9 (± 2) sows were added to each dynamic group at the beginning of each replicate and sows remained in these groups for 11 weeks. The number of unfamiliar sows (ie from different voluntary cubicle groups) added to each dynamic group was balanced across treatments. Sows were added to the groups at 1100h on day 1 of the replicate. Both dynamic groups were housed in identical split-yard systems (18.2 × 7.8 m) with slatted exercise and drinking areas and solid-floored kennel areas in both the pre- and post-feeding yards. The pre-feeding yard was separated from the post-feeding yard by an electronic feed station (Figure 1). Sows were fed individually in an electronic sow feeder (ESF) once a day and the feeding cycle began at 0730h. Each sow was allowed 13 min to consume their ration. All sows had finished their diet and passed into the post-feeding yard by 1600h and remained there until 0730h when the gate was opened and they moved back into the pre-feeding yard. All sows in this experiment had experience using an electronic feeding system.

Treatments

The composition of each concentrate ration is listed in Table 1. Sows on the control diet were fed 2.2 kg per day of the diet, while those on the high fibre diet were fed 2.85 kg per day. It is worth noting that no attempt was made to balance crude protein (CP) and lysine levels across treatments, and indeed both experimental treatments oversupplied CP and lysine. It was felt, on the basis of previous research (eg Mahan *et al* 1998; Cooper *et al* 2001; Yang *et al* 2008), that these differences were unlikely to significantly influence parameters measured.

Treatments were applied to two separate dynamic groups each containing 33 (± 3) sows, in a cross-over design, balanced for time effects, yard and sow group. Approximately nine sows were replaced (newly mated sows were added and sows due to farrow were removed) in each of these groups at 3-week intervals (each replacement constituting a replicate of the study). Three days before the introduction of the new sows the same number of sows were removed from the groups.

The control diet was applied to Group 1 and the high fibre diet was applied to Group 2 for the first three replicates and then the treatments were crossed over, with the control diet applied to Group 2 and the high fibre diet applied to Group 1. Prior to commencement of treatment, all sows on the high fibre diet were gradually introduced to this diet over a 5-day period. This involved feeding the sows a 50:50 mix of the high and low fibre diets for 3 days. Following this, the sows on Treatment 1 were provided with 100% high fibre diet for two days before observations began. All sows were fed the low fibre diet prior to the experiment and allocation of treatments. At the end of the high fibre treatment the sows were provided with a 50:50 mix of the high fibre diet and the control diet for 4 days before returning to the control diet.

Dietary analysis

Each new batch of concentrate diet was sampled (4 samples per dietary treatment in total) and chemical analysis carried out to determine the Neutral Detergent Fibre (NDF) and Acid Detergent Fibre contents of the diets using the Fibertec system (Van Soest 1976). The control diet contained 143.3 g kg^{-1} DM ADF and 284.8 g kg^{-1} DM NDF. The high fibre diet contained 220.0 g kg^{-1} DM ADF and 386.0 g kg^{-1} DM NDF.

Measurements

Video recordings of behaviour

Each replicate was recorded in real time for the first three days in week 1 and for the same three days in weeks 2 and 3. Animals were recorded in long play mode (six hours recorded onto a three hour tape via 16 cameras (Panasonic CCD cameras, WV-CP410) and a multiplexer (Panasonic Video Multiplexer, WJ-FS216). All parts of the split-yard systems, including the kennel and slatted areas, were observed.

Figure 1

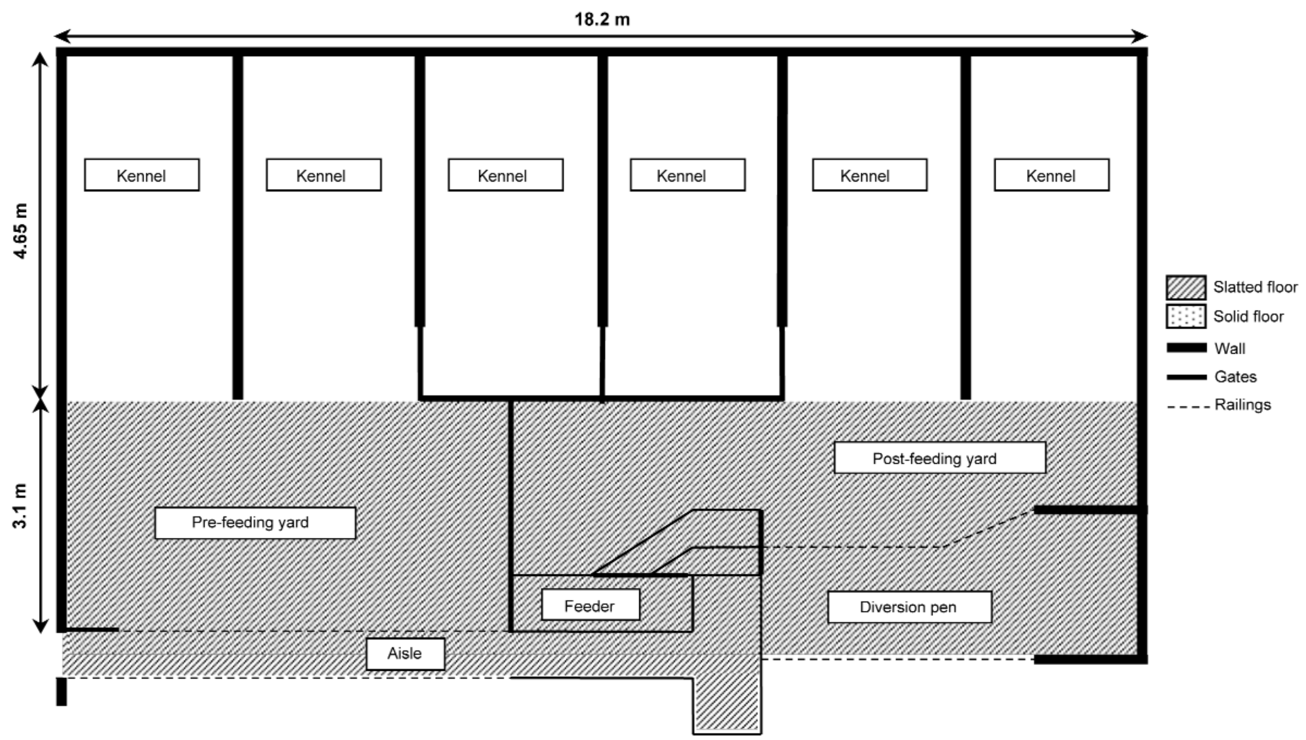

Diagram of one of the split yards.

General activities

General behaviour observations of newly introduced sows were made one day post mixing and on the same day in weeks 2 and 3. Observations were made instantaneously every hour from the video recordings over a 24-h period. Recordings were made of sow activity (Table 2), location (whether the sow was in the kennel or slatted area) (Figure 1) and posture (Table 2).

Direct observations

Focal observations

Focal observations were carried out to observe behaviours not readily visible from tapes. The observations were made on the morning and afternoon of two non-consecutive days of each week for the first three weeks that sows were in the group. Therefore, sows were observed on 12 occasions in total within each replicate. The ethogram of behaviours recorded is listed in Table 3. Observations of 5-min duration were made on a random selection of newly introduced animals and resident animals (three of each, six animals in total from each treatment in each replicate) between 0900–1100h and between 1300–1500h. The same animals were observed throughout each replicate. All the specified behaviours performed and received by the sows were recorded.

Sham-chew scans

All sows within the group were observed in a predetermined random order in the morning and afternoon of two non-consecutive days of each week for the first three weeks that sows were in the group. These observations were used to assess whether or not they were sham chewing, and also to assess the location of the sows (ie the slatted exercise area or the solid-floored kennel areas). In addition, instantaneous sham-chew scans were performed on newly introduced animals to the group every 15 min for two hours, beginning 15 mins after feeding one day a week during the first three weeks in the group. Whether or not each animal was performing sham-chewing behaviour was recorded during these scans, in addition to the location of the sow.

Aggressive behaviour

Aggressive interactions involving newly introduced sows were recorded between 1100 and 1500h on the day of introduction to the dynamic group. Each newly introduced sow was observed continuously for two minutes every hour, recording all aggressive interactions. Sows were recorded, alternating between yards for each observation, in a predetermined randomised order. The aggressive interactions that were recorded are listed in Table 4.

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Table 1 Levels of different ingredients used in the control and high fibre diets.

	Diet (kg)	
	Control	High fibre
Ingredients (g kg^{-1})		
Barley	534	204
Wheat	100	70
Home milled pollard	75	75
Sugarbeet pulp	80	140
GM Hipro soya	100	100
GM soya hulls		300
Molaferm (press)	30	30
Soya bean oil	35	35
Fine limestone	6	6
Monodicalcium phosphate	13	13
Salt (micro)	4.5	4.5
Sow breeder supplement*	2.5	2.5
Water	20	20
Formulated chemical analysis (g kg^{-1} DM or MJ kg^{-1})		
Crude protein	134.5	140.7
Crude fibre	50.3	147.3
Digestible energy	13.4	10.3
Lysine	0.61	0.73

* NS SOW 620 B from Nutrition Services International Ltd. Ash 83.6%, calcium 29.1%, vitamin A 3,200,000 iu kg^{-1}, vitamin D3 800,000 iu kg^{-1}, vitamin E as alpha-tocopherol 20,000 iu kg^{-1}, copper as cupric sulphate 4,000 mg kg^{-1} and selenium 60 mg kg^{-1}.

Table 2 Ethogram of activities.

Activity	Description
Exploration	Snout in contact with walls, floors, railings etc (except drinkers, or gates at entrance or exit of feeder)
Explore feeder	Snout in contact with gates at entrance or exit of feeder
Explore drinkers	Snout in contact with drinker
Social behaviour	Any contact (except aggressive) with snout and any part of the body of another pig
Social aggressive	Sow involved in any behaviours listed in Table 4
Locomotion	All four legs or both front legs are moving and the snout is not in contact with any substrate: animal is standing
Other	Any other behaviour not listed

Injury scores

Aggression-related injuries to the newly introduced sows were scored one week post mixing. Injuries were recorded on 12 areas of the body: head, left ear, right ear, left shoulder, right shoulder, back, right flank, left flank, right hindquarter, left hindquarter, vulva and tail. Aggression-related injuries were defined as raised skin with redness or broken skin with or without redness and ≥1 cm in length. Injuries were recorded on a scale of 0 to 3 as follows: 0 = no injuries; 1 = one to three injuries; 2 = four to six injuries; and 3 = more than six injuries.

Physiological measurements

Blood samples were taken from all newly introduced animals by anterior vena cava venipuncture, one week before entering the dynamic group and at the end of the first week in the dynamic group. Sows to be sampled were diverted away from the rest of the group to avoid disturbance, and were sampled within two minutes of being approached. All samples were taken at approximately 1400h using lithium heparinised syringes. Samples were centrifuged immediately at 2,000 g for 10 min at 5°C. Plasma was stored at –20°C until analysis. Determination of the acute phase protein, haptoglobin (Hp) was made using commercially available assays (Tridelta Development Ltd, Maynooth, Co Kildare, Ireland) which measure the preservation of the peroxidase activity which is directly proportional to the amount of haptoglobin present in the specimen. Plasma cortisol was also determined by an enzyme immunoassay (DRG-Diagnostics, Marburg, Germany).

Statistical analysis

The influence of the high fibre diet on focal animal behaviour, injury scores, haptoglobin and plasma cortisol (log transformation was carried out on the plasma cortisol results to normalise the data) were analysed by analysis of variance (ANOVA). The haptoglobin and plasma cortisol were also analysed by ANOVA to assess the effect of introduction to the dynamic group. In these analyses, treatment group means within each replicate were used as independent experimental units to allow treatment comparisons. Scan observations of general activities, which included recording location, posture and activity, were analysed by repeated measures ANOVA (blocked for replicate). Location, state and activity were expressed as proportions of total available time intervals. For example, in a particular treatment, a group of nine newly introduced sows had 216 available time intervals within each day (9 × 24 scans in each 24-h period), and the proportion of these intervals in which the animals were in a particular location or involved in a particular state or activity was calculated. In this analysis, group means per day within each replicate were used as experimental units. Aggressive behaviour post mixing was analysed using Fisher's Exact test. In this analysis, data were summed for all sows to give one value for each treatment × sow type category (ie newly introduced sows or resident). The influence of the high fibre diet on the average proportion of sows performing sham-chewing

Table 3 Ethogram of behaviours recorded directly by focal observation.

Behaviour	Description
Positive social behaviour	
Nosing	Sniffing, touching with snout or rubbing any part of another sow
Chewing	Nibbling, suckling or chewing any part of another sow (except vulva)
Agonistic behaviour	
Aggressive biting	Biting another sow (except tail or vulva) but not as part of a head thrust (often repeated in rapid succession)
Vulva biting	Nibbling, sucking or chewing the vulva of another sow
Fighting	Mutual pushing parallel or perpendicular ramming or pushing of the opponent with the head, with or without biting in rapid succession: lifting the opponent by pushing the snout under its body
Head thrusting	Ramming or pushing penmate(s) with head (with or without biting)
Displacing behaviour	
Displacing from lying	Displacing another sow from its lying area
Displacing from feeder	Displaying sow from feeder
Resting behaviour	
Inactive (alert)	Sitting, standing or lying with eyes open
Lying with eyes closed	Lying inactive with eyes closed
Investigative behaviour	
Explore floor	Sniffing or nosing any part of the floor
Explore fixtures	Sniffing, nosing, sucking or chewing any object which is part of ther pen, ie walls, gates, barriers, feeder, pipes, etc
Stereotypic behaviour	
Sham chewing	Chewing with nothing apparently in the mouth
Locomotion	
Locomotion	Any whole body movement, includes walking
Ingestive behaviour	
Feeding	Sow feeding in feed cubicle
Drinking	Sow drinking from water nipple
Elimination	
Elimination	Defaecation or urination
Other	
Other	Any other behaviour not listed

behaviour from the whole group, and from the detailed post-feeding scans made on the newly introduced sows, was analysed using Binomial Regression analysis. All variation in ANOVA was adjusted for yard effects and is expressed as the standard error of the mean (SEM). All data were analysed using Genstat 5 (Lawes Agricultural Trust 1989).

Additional ANOVA analyses were carried out to identify if there were differences between the individual replicates, particularly between replicates where treatments had been alternated between the yards versus consecutive replicates where treatments remained in the same yard. None of the key parameters (focal behaviours, sham chewing, resting behaviours and agonistic behaviours) were significantly affected by replicate. There were also no significant differences between replicates where treatments have been alternated between the yards versus consecutive replicates where treatments remained in the same yard.

Results

General activities

The influence of providing a high fibre diet on the location, posture and activity of newly introduced sows to the

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Table 4 Ethogram of post-mixing aggressive behaviours.

Behaviour	Description
Bite	Biting any part of another sow (except vulva), but not as part of head thrust (often repeated in rapid succession)
Vulva bite	Biting the vulva of another sow
Head thrust	Ramming or pushing another sow with the head (with or without biting)
Fight	Mutual pushing parallel or perpendicular, ramming or pushing of the opponent with the head, with or without biting in rapid succession: lifting the opponent by pushing the snout under the body
Chase	Moving rapidly in pursuit of another sow
Threat	Being in head-to-head contact with another sow and the other sow actively withdrawing

Table 5 Influence of providing a high fibre diet on the average proportion of time spent in different behaviours by newly introduced sows to a dynamic group.

Parameter	High fibre	Control	SEM	$F_{1,10}$	*P*-value
Overall					
Kennel areas	0.893	0.788	0.0328	5.10	< 0.05
Slatted areas	0.106	0.210	0.0326	5.07	< 0.05
Sitting	0.009	0.018	0.0022	7.68	< 0.05
Standing	0.226	0.293	0.0212	4.94	0.05
Lying	0.765	0.689	0.0216	6.12	< 0.05
Exploration	0.217	0.296	0.0214	6.79	< 0.05
Within kennel areas					
Sitting	0.028	0.018	0.0023	6.63	< 0.05
Standing	0.136	0.178	0.0132	5.06	< 0.05
Lying	0.854	0.803	0.0147	5.92	< 0.05
Exploration	0.146	0.195	0.0145	5.76	< 0.05
Within slatted areas					
Sitting	0.003	0.021	0.0072	3.09	ns
Standing	0.970	0.845	0.0367	5.77	< 0.05
Lying	0.027	0.134	0.0321	5.54	< 0.05
Exploration	0.787	0.784	0.0414	0.00	ns

dynamic group is shown in Table 5. Newly introduced sows in the high fibre treatment spent proportionally more time in the kennel areas and less time in slatted areas compared to newly introduced sows in the control treatment ($P < 0.05$). Sows in the high fibre treatment spent less time standing and sitting and more time lying overall than sows in the control treatment ($P < 0.05$).

Treatment also had an effect on exploration, with sows in the high fibre treatment spending proportionally less time exploring overall ($P < 0.05$), and exploring in kennel areas ($P < 0.05$) compared to sows in the control treatment. None of the other activities differed between treatments ($P > 0.05$).

Focal observations

Sows on the high fibre diet spent a greater percentage of time lying with eyes closed (High Fibre: 43.8, Control: 28.0, SEM 3.25%, $F_{1,10} = 11.80$; $P < 0.01$), while sows on the control diet spent more time sham chewing (High Fibre: 7.2, Control: 28.8, SEM 1.55%, $F_{1,10} = 96.76$; $P < 0.001$). The frequency of aggressive behaviour was low, and there were no overall treatment differences (High Fibre: 0.03, Control: 0.05, SEM 0.007 (occurrences per min), $F_{1,10} = 3.72$; $P > 0.05$). However, sows in the control treatment performed more instances of head thrusting (High Fibre: 0.00, Control: 0.02, SEM 0.001 (occurrences per min), $F_{1,10} = 16.98$; $P < 0.01$) and biting (High Fibre:

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0.01, Control: 0.02, SEM 0.002 (occurrences per min), $F_{1,10} = 5.87$; $P < 0.05$) than sows on the high fibre diet. There were no other significant differences between treatments in focal animal behaviour.

Sham-chew scans

Observations of the entire group showed that a larger proportion of sows performed sham chewing in the control treatment compared to the high fibre treatment (High Fibre: 0.178, Control: 0.313; $P < 0.001$). In both treatments, sows performed more sham chewing in the post-feeding yard compared to the pre-feeding yard (High Fibre: pre-feeding yard 0.06, post-feeding yard 0.30; Control: pre-feeding yard 0.13, post-feeding yard 0.50; $P < 0.01$).

The post-feeding sham-chew observations of newly introduced sows showed that these sows also performed proportionally more sham chewing during this period in the control treatment compared to the high fibre treatment (High Fibre: 0.249, Control: 0.378; $P < 0.001$). Newly introduced sows performed more sham chewing in the slatted areas compared to the solid floor areas (Slatted area: 0.420, Kennel area: 0.206; $P < 0.001$).

Post-mixing aggression

There was no effect of treatment on the average proportion of observations during the post-mixing period where sows were observed to perform aggressive behaviour (High Fibre: 0.27, Control: 0.24; $P > 0.05$).

Injury scores

There was no significant difference between treatments in total injury scores (High Fibre: 2.76, Control: 4.15, SEM 0.977, $F_{1,10} = 1.06$; $P > 0.05$).

Physiological measures

There was no effect of treatment on differences between post- and pre-mixing plasma cortisol levels (High Fibre 1.34, Control: 1.44, SEM 0.114 ng ml^{-1}, $F_{1,43} = 0.29$; $P > 0.05$) when sows were introduced to the dynamic group. Additionally, these factors did not affect levels of haptoglobin (High Fibre: 0.73, Control: 0.64, SEM 0.080 mg ml^{-1}, $F_{1,43} = 0.56$; $P > 0.05$). The levels of plasma cortisol and haptoglobin all fell within the expected normal ranges for pigs (Zanella *et al* 1998; Sutherland *et al* 2006).

Discussion

The high fibre diet resulted in sows spending more time resting, whereas sows in the control treatment spent more time exploring. This is in agreement with a previous study by Ramonet *et al* (1999), which found that feeding high levels of fibre to sows reduced standing activity by 25% compared to low fibre diets. Other studies found that increasing the level of dietary fibre reduced exploration (Robert *et al* 1993; Brouns *et al* 1994; Zonderland *et al* 2004). Exploratory behaviour in pigs is thought to be an expression of the need to forage or feed (Lawrence & Terlouw 1993). Hence, a reduction in foraging behaviour is likely to reflect improved welfare for sows as it may be an indication of increased satiety (Ramonet *et al* 1999). Increased lying behaviour is also thought to reflect increased satiety in sows, and thus improved welfare (Ramonet *et al* 1999).

Newly introduced sows in the high fibre treatment spent proportionally more time in the kennel areas compared to newly introduced sows in the control treatment. This increased time in the kennel areas may have reflected an increased motivation to rest in the high fibre treatment. The kennel areas have the advantage of being warmer and drier compared to the slatted areas, and therefore may be viewed as a prioritised resource. Previous research suggests that sows newly introduced to a large dynamic group often have difficulty gaining access to prioritised resources (O'Connell *et al* 2003). It is possible that the increased use of the kennel areas shown in the high fibre treatment in the present study may reflect an improved ability to gain access to resources and consequently improved social integration (Spoolder 1998). In the current study, there was also a reduction of exploratory behaviour within kennel areas in the high fibre treatment, and this would have the additional benefit of reducing disturbance to resting animals (Durrell 2000).

In general, aggression occurred at a very low frequency and overall levels during the immediate post-mixing period did not differ between treatments. This explains the lack of a difference in injury scores between treatments. Low levels of post-mixing aggression were previously found in the same housing system (O'Connell *et al* 2003, 2004), indicating that this particular system is beneficial in reducing aggression within large groups of sows. However, focal observations showed that sows in the control treatment performed more instances of head thrusting and biting than sows in the high fibre diet. This could suggest that live focal observations allowed greater detection of subtle treatment differences in aggressive behaviour than video observations, or alternatively, that high fibre diets ameliorate some forms of aggression (ie those which do not arise directly from mixing) in group-housed sows. The suggestion that high fibre diets reduce levels of aggressive behaviour in group-housed sows is supported by earlier findings (Meunier-Salaün *et al* 2001).

In the present study, sows on the high fibre diet showed a significant reduction in sham-chewing behaviour. This provides further evidence that the high fibre diet promoted satiety, which may have been due to the consumption of fibrous material which is associated with increased 'gut fill' (Lawrence & Terlouw 1993; Whittaker *et al* 1999). In addition, satiety due to increased dietary fibre levels is associated with a prolonged energy supply produced by increased hindgut fermentation (Ramonet *et al* 2000a). This effect is related to the source of fibre used, as soluble fibres are more fermentable than insoluble fibres (Ramonet *et al* 2000b). Indeed, soluble fibres have been found to effectively reduce the occurrence of stereotypic behaviours (Ramonet *et al* 1999). In the present study, increased dietary fibre levels were achieved through use of sugarbeet pulp and soyabean hulls, which provide high and moderate levels of soluble fibre, respectively (Johnston *et al* 2003;

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Jørgensen *et al* 2007), and this may have contributed to the effectiveness of this regime in reducing stereotypic behaviour. In both the high fibre treatment and the control treatment, sows performed more sham chewing in the post-feeding yard than the pre-feeding yard. This is in agreement with the suggestion that sham chewing is stimulated by the ingestion of feed (Spoolder *et al* 1995).

Levels of haptoglobin did not differ between treatments and there was no effect of introduction to the dynamic group on this parameter. This concurs with previous research which shows that when pigs are exposed to acute stressors, such as mixing, there is a lack of effect on haptoglobin levels (Hicks *et al* 1998). In fact, it has been suggested that acute phase proteins may be limited in their use as stress indicators in domestic animals (Levrino & Robinson 2003). High levels of individual variation in physiological parameters (such as cortisol levels) are thought to overshadow experimental treatment effects (Levrino & Robinson 2003). This individual variation may be caused by factors such as social rank (Nicholson *et al* 1993). This variation in physiological measures led some authors to suggest that behavioural measures are more reliable indicators of stress (Hicks *et al* 1998; Levrino & Robinson 2003).

Conclusion

Provision of a high fibre diet had a positive effect on the welfare of group-housed dry sows. Sows fed the high fibre diet spent more time resting and using the kennel areas, and less time performing stereotypic behaviours and certain aggressive behaviours. These improvements were not reflected in the physiological parameters, which did not differ between treatments.

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