Animal Welfare 2011, 20: 633-640
ISSN 0962-7286

The effect of increasing dietary fibre and the provision of straw racks on the welfare of sows housed in small static groups

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Abstract

This study assessed the effects of increasing dietary fibre levels in concentrate rations and providing access to straw in racks on the welfare of pregnant sows housed in small static groups. In a 2 × 2 factorial design experiment, 128 Large White × Landrace pregnant sows were offered one of two diets: (i) High fibre diet with 9% crude fibre, or (ii) Control diet with 4.5% CF, and one of two levels of access to a foraging substrate: (i) access to straw in racks or (ii) no straw. The study was replicated eight times using groups of four sows, and treatment periods lasted four weeks. Sows were housed in pens with voluntary cubicles and a slatted exercise area and were offered a wet diet twice a day. Back-fat levels were measured before sows were mixed into groups at 28 days post partum, and four weeks later. Aggressive interactions were recorded on the day of mixing, and injury scores were recorded one week post mixing. Scan sampling was used to collect data on general activity, posture and location of the sows, and on sham-chewing and bar-biting behaviours across the treatment period. In addition, detailed focal observations were carried out on all sows across the treatment period. Straw usage was also recorded. There were no treatment effects on changes in back-fat levels over the treatment period. Treatments had no effect on post-mixing aggression or on injury scores. However, focal observations showed that sows with access to straw were involved in fewer bouts of head-thrusting over the treatment period. Control diet sows spent more time inactive than sows on the high fibre diet, however high fibre diet sows spent more time lying with eyes closed than sows on the control diet. Sows on the high fibre diet with access to straw showed less sham-chewing and bar-biting behaviour than sows in other treatments. These results show that although a diet containing 9% crude fibre promoted resting behaviour, it was necessary to combine it with access to straw to reduce stereotypic behaviour of sows in small static groups.

Keywords: *animal welfare, behaviour, fibre, sows, static groups, straw rack*

Introduction

European Union pig welfare legislation requires that pregnant sows be provided with bulky or high fibre diets (Council Directive 2001/88/EC). This legislation arose because these animals are often fed a restricted diet in order to optimise reproductive performance (Ramonet *et al* 2000a). However, this can leave the animals feeling hungry (Ramonet *et al* 2000b) and has been linked with increased levels of aggression (Jensen *et al* 2000), increased physical activity (De Leeuw *et al* 2005) and the development of stereotypies (Lawrence & Terlouw 1993).

This legislative requirement can be met by increasing the fibre content of the concentrate ration and/or through providing sows with access to a foraging substrate. However, the effectiveness of these regimes may differ depending on how they are implemented. For example, the significance of increasing dietary fibre levels differs depending on the fibre level used (Ramonet *et al* 1999; Bergeron *et al* 2000), the source of fibre (Matte *et al* 1994; Ramonet *et al* 2000a) and the method of feeding, ie wet or dry feeding (Bergeron *et al* 2002; Scott *et al* 2007) and once or twice a day feeding (Robert *et al* 2002). There has been a significant amount of research on the effect of increasing the fibre content of the concentrate ration using sugar beet pulp in *ad libitum* dry-feeding systems (Brouns *et al* 1995). In addition, wet feeding pigs is becoming increasingly popular due to the fact that it is a cost-effective method of feeding as it uses low dry matter products (Scott *et al* 2007). There are a number of health and welfare benefits believed to be associated with liquid feeding systems. For example, satiety levels in sows may be further improved by wet feeding which can result in improved gut fill (Bergeron *et al* 2002; Scott *et al* 2007). However, there is limited information available on the impact of wet feeding on pig health and welfare (Scott *et al* 2007).

Table 1 Ingredients and chemical analysis of high and low fibre diets.

	Diet (kg)	
	Control	High fibre
Ingredients (g kg^{-1})		
Barley	892.9	742.9
Soya hulls	0	150
Soya hi-pro	75	75
Fat soya oil	10	10
L-lysine HCl	0.5	0.5
Di cal phos	5	5
Limestone flour	11	11
Salt	4.0	4.0
Vitamins-minerals	1.5	1.5
Phytase 500 iu g^{-1}	0.1	0.1
Formulated chemical analysis (g kg^{-1} DM or MJ kg^{-1})		
Crude protein	132	133
Crude fibre	45	89
Digestible energy	13.0	11.0
Lysine	6.19	6.70

The effectiveness of providing sows with access to a foraging substrate such as straw may also differ depending on how it is offered. Research shows that providing group-housed sows with access to straw as a bedding substrate improves welfare levels (Tuyttens *et al* 2005). However, providing straw as bedding may not be possible in slatted systems, or in areas where straw is in short supply. Providing sows with access to straw in racks led to limited welfare benefits for sows housed in large dynamic groups, however accessibility to the racks appeared to be a key issue (Stewart *et al* 2008). It is possible that the effectiveness of providing sows with access to straw in racks is improved when sows are housed in small static groups.

The aim of this study was to assess the relative benefits of increasing dietary fibre levels (through use of soya hulls), or of providing access to straw in racks, for sows housed in small static groups and fed using a wet feeding system. Whether or not there were any additive benefits associated with providing both regimes was also assessed. Welfare was assessed using behavioural observations and injury scores.

Materials and methods

Experimental design and treatments

The effect of increasing fibre level in the concentrate ration and providing access to straw racks was assessed in a 2 × 2 factorial design experiment with eight replicates. Sows were housed in static groups of four and the experimental period lasted four weeks. There were four experimental periods with eight groups of sows being formed at the start of each period (ie two replicates per period).

Treatments were as follows: (1) sows were fed a control diet and had no access to straw; (2) sows were fed a control diet and had access to straw in racks; (3) sows were fed a high fibre diet and had no access to straw; and (4) sows were fed a high fibre diet and had access to straw in racks.

The control diet was formulated to contain 4.5% crude fibre (CF) and 13.0 MJ kg^{-1} digestible energy (DE). The high fibre diet was formulated to contain 9% CF and 11.0 MJ kg^{-1} DE. The individual dietary ingredients and chemical analysis are shown in Table 1. The diets were calculated to be iso-energetic; sows in Treatments 1 and 2 were offered 2.25 kg day^{-1} of the control diet, while sows in Treatments 3 and 4 were offered 2.65 kg day^{-1} of the high fibre diet. Sows in Treatments 3 and 4 were offered the high fibre diet for one week prior to the start of the experimental period to allow them to become accustomed to it.

In Treatments 2 and 4, straw was provided in four individual racks (0.40 × 0.54 m [height × width] with 5 cm^2 mesh) which were located in the voluntary cubicles. Each rack was attached to the wall and suspended 0.3 m above the feeding trough. The racks were filled with a weighed amount of chopped barley straw at 0800 and 1530h (offering an average of 0.32 kg straw sow^{-1} day^{-1}) on a daily basis.

Animals, housing and management

One hundred and twenty-eight Large White × Landrace sows were used. These consisted of primi- and multiparous animals with an average parity of 3 (± 2). Both treatments and individual groups were balanced for parity. Prior to the experimental period sows were housed individually in stalls (2.2 × 0.65 m; length × width). Sows were artificially inseminated approximately 28 days prior to moving into group housing. Eight groups of four sows were randomly allocated to treatments every five weeks with sows being moved into the experimental pens at 1100h on day 1 of the experimental period. Four pens in each of two similar dry sow houses were used for the experiment. Each pen contained four voluntary cubicles (including feeders) (1.0 × 0.6 m; length × width) and a slatted exercise area (2.8 × 2.4 m) yielding a total area of 10.56 m^2 (2.64 m^2 per sow). The sows were offered a wet ration, which had a ratio of four parts water to one part concentrate, twice a day at 0830 and 1500h. For identification purposes the sows were marked with an individual number on their back.

Aggressive behaviour post mixing

Aggressive interactions were recorded between 1100 and 1400h on the day of group formation. Each group was observed continuously for 10 min immediately post mixing and then for 10 min every 30 min until there was a total of four observations (ie 40 min) for each group. All aggressive interactions were recorded (Table 2). The proportion of observations recording sows performing aggressive behaviours were calculated for each group.

https://doi.org/10.1017/S0962728600003274 Published online by Cambridge University Press

Table 2 Ethogram of aggressive behaviours that were recorded during the post-mixing period.

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 its 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 3 Ethogram of focal behaviours that were recorded.

Behaviour	Description
Nosing	Sniffing, touching with nose or rubbing any part of another sow
Chewing	Nibbling, suckling or chewing any part of another sow (except vulva)
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 pen-mate(s) with head (with or without biting)
Displacing from lying	Displacing another sow from its lying area
Displaying from cubicle	Displaying sow from voluntary cubicle
Inactive (alert)	Sitting, standing or lying inactive with eyes open
Lying with eyes closed	Lying inactive with eyes closed
Exploration	Sniffing, nosing, sucking or chewing any part of the floor, or any objects which is part of the pen, ie walls, gates, barriers, straw racks, feed troughs, pipes, etc
Sham chewing	Chewing with nothing apparently in mouth
Bar biting	Continuous chewing on the bars of the pen
Locomotion	Any whole body movement, includes walking
Feeding	Sow feeding in voluntary cubicle
Elimination	Defaecation or urination
Other	Any other behaviour not listed

Focal observations

Each sow was observed continuously for 5 min on two occasions during each of two non-consecutive days per week. Observations took place between 0900 and 1100h and between 1300 and 1500h. All sows were observed on 16 occasions, yielding a total of 80 min (16 × 5 min) of continuous recording per animal. The ethogram of behaviours is listed in Table 3. All the specified behaviours performed and received by the sows during these observations were recorded.

Sham chewing and bar biting

Each sow was observed during two separate time-periods within each of two non-consecutive days each week of the treatment period. These time-periods were between 0900 and 1100h and from 1300 to 1500h. During these time-

Table 4 Ethogram of general activities and postures that were recorded.

Activity	Description
Active	The animal is involved in locomotion, exploration or any other activity
Inactive (alert)	Sitting, standing or lying inactive with eyes open
Lying with eyes closed	Lying inactive with eyes closed
Other	Any other behaviour not listed
Posture	**Description**
Stand	The animal is standing up
Sit	The animal is sitting on its back legs
Lie	The animal is lying down

https://doi.org/10.1017/S0962728600003274 Published online by Cambridge University Press

periods sows were scanned instantaneously at 5-min intervals to assess whether or not they were sham chewing (chewing with nothing apparently in the mouth) or biting on bars in the pen. Therefore, in total, there were 24 scans per sow per observation, and 384 scans (24 scans × 16 observation) per sow over the treatment period.

General activity, posture and location in pen

One day post mixing (day 2), and on the same day in weeks 2, 3 and 4, each of the eight groups were observed instantaneously by direct observation every hour for 12 h commencing at 0800h. The activity (Table 4), location (slatted dunging/exercise area or voluntary cubicle) and posture (Table 4) of each sow in the group was recorded.

Injury scores

All sows were inspected for aggression-related injuries at one week post mixing. Injuries were scored on a scale of 0–3 (see below). Twelve locations on the body were inspected: head, left ear, right ear, left shoulder, right shoulder, back, right flank, left flank, right hindquarter, left hindquarter, vulva and tail. The scores were summed to give an overall injury score. The scale used to score injuries is described as follows: (0) no injuries; (1) one to three injuries; (2) four to six injuries; and (3) more than six injuries.

Back-fat depth and bodyweight

Sows were weighed before they entered the groups and at the end of the experimental period (four weeks later). Bodyweight change over the treatment period (weight at end of treatment minus weight at the start of the treatment) was calculated. Back-fat depth at the P2 site (P2 level, 65 mm from the edge of the dorsal mid-line, at the level of the last rib [McGowan & McCann 2006]) of all sows was measured at the same time as weighing using a Renco Lean Meter® (Renco Corporation, North Minneapolis, MN, USA).

Straw usage

Each day the straw remaining in the racks was weighed before being replenished. The mean daily straw usage was calculated by subtracting this weight from the weight of the straw placed in the rack the previous day.

Statistical analysis

The influence of the high fibre diet and provision of straw racks on injury scores, back-fat levels and bodyweights were analysed by analysis of variance (ANOVA). Focal animal behaviours were analysed by ANOVA (blocked for time of day, ie am or pm). The influence of the high fibre diet on the use of the straw was also analysed by ANOVA. In these analyses, treatment group means were used as the experimental units. Location, posture and activity were analysed using repeated measures ANOVA and expressed as total available time intervals. For example, a particular treatment group of four sows had 48 available time intervals within each day (4 × 12 scans in each 12-h period), and the proportion of these intervals in which the animals were observed to be in a particular posture, activity or location was calculated. In this analysis, group mean levels per day within each replicate were used as experimental units. Aggressive behaviour post mixing was analysed using Fisher's exact test. Data were summed for all groups to give one value for each treatment for proportion of observations where an aggressive interaction was shown in the group, or proportion of the group that showed aggression. The influence of the high fibre diet and the provision of straw on the average proportion of sows performing sham-chewing and bar-biting behaviours was analysed using binomial regression analysis. Treatment group means were used as the experimental units. All variation in ANOVA was adjusted for house effects and expressed as the standard error of the mean (SEM). All data were analysed using Genstat 5 (Lawes Agricultural Trust 1989).

Results

Aggressive behaviour post mixing

There was no effect of increasing the fibre content of the diet, or providing access to straw on the proportion of observations where aggressive behaviours occurred in the post mixing period (High fibre: 1.00, Control: 0.94, $P > 0.05$; Straw: 0.94, No straw: 1.00, $P > 0.05$).

Focal observations

Sows on the high fibre diet performed fewer bouts of chewing their pen mates than those on the control diet (Control: 0.042, High fibre: 0.010, SEM (± 0.0083), $F_{1,27} = 7.77$, $P < 0.05$). Provision of straw reduced the occurrence of head thrusting relative to no straw being provided (No straw: 0.005, Straw 0.001, SEM (± 0.0010), $F_{1,27} = 6.75$, $P < 0.05$). There was a significant interactive effect between dietary treatment and access to straw on exploratory behaviour. Sows provided with high fibre diets and straw in racks showed increased levels of exploratory behaviour (Control: No straw 30.65^{a}, Straw 43.97^{ab}, High fibre: No straw 39.09^{ab}, Straw 51.74^{b}, SEM (± 5.294), $F_{1,27} = 6.02$, $P < 0.05$). There were no other significant differences between treatments in focal animal behaviour.

Sham chewing and bar biting

There was a significant interactive effect between dietary fibre level and the provision of straw on sham-chewing behaviour. The combination of straw and the high fibre diet resulted in a greater reduction in sham-chewing behaviour than provision of straw alone (Control: No straw 0.294^{a}, Straw 0.149^{b}, High fibre: No straw 0.290^{a}, Straw 0.088^{c}, $P < 0.001$). In addition, there was a significant reduction in the proportion of sows performing bar-biting behaviour when the high fibre diet and straw in racks were provided together (Control: No straw 0.003^{a}, Straw 0.003^{a}, High fibre: No straw 0.003^{a}, Straw 0.001^{b}, $P < 0.05$). (NB Statistically significant differences between treatments are indicated by different superscripts).

General activity, posture and location in pen

The influence of providing a high fibre diet and straw in racks on selected parameters is shown in Table 5. Sows on the control diet spent proportionally more time inactive than sows on the high fibre diet ($P < 0.05$), whereas sows on the high fibre diet spent proportionally more time lying with

https://doi.org/10.1017/S0962728600003274 Published online by Cambridge University Press

Table 5 The influence of providing a high fibre diet and straw in racks on the activity levels (expressed as a proportion of time) of sows in static groups.

Parameter	Control diet	High fibre diet	SEM	$F_{1,27}$	*P*-value
Slatted area					
Active	0.496	0.552	0.0586	0.47	ns
Inactive	0.238	0.117	0.0314	7.38	< 0.05
Lying eyes closed	0.266	0.329	0.0523	0.73	ns
Other	0.001	0.002	0.0143	0.12	ns
Voluntary cubicles					
Active	0.356	0.349	0.0404	0.01	ns
Inactive	0.231	0.104	0.0204	13.99	< 0.001
Lying eyes closed	0.414	0.546	0.0360	6.81	< 0.05
Other	0.000	0.001	0.004	1.00	ns
Overall					
Active	0.355	0.367	0.0183	0.22	ns
Inactive	0.240	0.117	0.0237	13.57	< 0.001
Lying eyes closed	0.405	0.516	0.0231	11.50	< 0.05
Other	0.000	0.001	0.0007	0.39	ns
Slatted area	0.158	0.180	0.0124	1.54	ns
Voluntary cubicles	0.568	0.676	0.4360	3.08	ns
	No straw	**Straw**	**SEM**	$F_{1,27}$	***P*-value**
Slatted area					
Active	0.582	0.466	0.0586	1.99	ns
Inactive	0.161	0.193	0.0314	0.52	ns
Lying eyes closed	0.253	0.341	0.0523	1.40	ns
Other	0.003	0.000	0.0143	1.88	ns
Voluntary cubicles					
Active	0.328	0.377	0.0404	0.76	ns
Inactive	0.182	0.152	0.0204	0.76	ns
Lying eyes closed	0.490	0.470	0.0360	0.105	ns
Other	0.001	0.000	0.0004	1.00	ns
Overall					
Active	0.376	0.345	0.0183	1.37	ns
Inactive	0.179	0.178	0.0237	0.00	ns
Lying eyes closed	0.444	0.476	0.0231	0.96	ns
Other	0.001	0.000	0.0007	1.57	ns
Slatted area	0.174	0.163	0.0124	0.37	ns
Voluntary cubicles	0.622	0.622	0.4360	0.00	ns

their eyes closed than sows on the control diet ($P < 0.05$). There were no other significant treatment effects on activity, posture and location parameters.

Injury scores

There was no main or interactive effects of treatment on injury scores (Control 5.28, High fibre 6.02, SEM [± 0.557], $F_{1,27} = 0.87$, $P > 0.05$; No straw 5.95, Straw 5.34, SEM [± 0.557], $F_{1,27} = 0.60$, $P > 0.05$).

Back fat and bodyweight

Sows on the high fibre diet gained more weight during the treatment period than those on the control diet (Control: 8.93, High fibre: 18.57, SEM [± 0.916] kg, $F_{1,27} = 55.39$, $P < 0.001$). Bodyweight gain was not affected by access to straw racks, and there were no interactive effects between treatments ($P > 0.05$). The change in back fat was not affected by diet (Control 0.18, High fibre 0.09,

https://doi.org/10.1017/S0962728600003274 Published online by Cambridge University Press

SEM [± 0.097] mm, $F_{1,27}$ = 0.44, $P > 0.05$) or access to straw racks (No straw 0.04, Straw 0.23, SEM [± 0.096] mm, $F_{1,27}$ = 1.95, $P > 0.05$). There were no significant differences between treatments in back-fat depths at the end of the treatment period (average back-fat depth 13.69 [± 0.654mm]).

Straw usage

On average, the sows were offered 0.32 kg sow^{-1} day^{-1} of chopped barley straw, and approximately 0.27 kg straw sow^{-1} day^{-1} was used. The dietary treatments had no effect on the total amount of straw used each week (Control: 17.0, High fibre: 17.1, SEM [± 4.91] kg, $F_{1,32}$ = 0.01, $P > 0.05$).

Discussion

In contrast to previous studies (Robert *et al* 1993; Ramonet *et al* 1999) the high fibre diet alone did not reduce stereotypic behaviour; in particular sham-chewing behaviour as overall bar-biting levels were low. This may have been because the level of crude fibre used in the present study (9.5%) was lower than that used in previous studies that found reductions in stereotypic behaviour (18% crude fibre: Ramonet *et al* 1999; 23% crude fibre: Bergeron *et al* 2000 and 15% crude fibre: Stewart *et al* 2007). In addition, sows were fed twice daily in the present study and this may have contributed to the lack of a main effect of high fibre diets on stereotypic behaviour. Feeding a high fibre diet once a day is a more effective method of reducing feeding motivation than feeding the same amount of diet in two separate meals (Robert *et al* 2002; Holt *et al* 2006). Hence, the combination of a lower fibre level and feeding twice daily may have reduced the gut-fill effects of the high fibre diet in the current study. The source of the fibre used in the high fibre diet may also have influenced the effectiveness of this treatment regime in reducing stereotypic behaviour. It is possible that soya hulls have a less satiating effect than other fibrous materials, such as sugar beet pulp, because soyabean hulls do not appear to be very effective in reducing stereotypic behaviour (Holt *et al* 2006). Previous studies reported that wet feeding results in better gut fill than dry feeding (Bergeron *et al* 2002; Scott *et al* 2007). Although sows were fed a wet diet in the current study, this method of feeding did not have an effect on stereotypic behaviour possibly because of the reasons discussed above, ie fibre source and the fact that it was fed in two meals.

The provision of straw in racks reduced the performance of stereotypic behaviour. This may have been due to increased gut fill associated with consuming the straw (Ramonet *et al* 1999), and/or because the straw allowed the sows to perform increased levels of foraging behaviour (Spoolder *et al* 1997). Previous research found that providing 0.3 kg straw day^{-1} in racks to sows housed in large, dynamic groups had no effect on stereotypic behaviour (Stewart *et al* 2008). However, in that study, straw was provided in two racks to large groups of approximately 35 sows, and therefore less accessible than in the current study. This was reflected in lower levels of straw usage per sow compared to the current study. This quantity would probably have been inadequate to improve gut fill (Tuyttens *et al* 2005). Thus, accessibility is a key factor influencing effectiveness of providing group-housed sows with access to straw in racks in reducing stereotypic behaviour. In the present study, the greatest reduction in stereotypic behaviour was achieved when straw was provided in combination with the high fibre diet. It is probable that in this case straw acted as a supplementary fibre source that improved gut fill to the point that feeding motivation and hence the performance of stereotypic behaviour was dramatically reduced.

The fact that the sows used the majority of the straw available to them indicates that their motivation to feed and forage was high and sustained (Terlouw & Lawrence 1993) in both treatments. These findings would also imply that the dietary fibre level in the high fibre treatment was too low to have a significant impact on satiety levels. Nevertheless, the reduction in stereotypic behaviour brought about by the high fibre diet in combination with access to straw in this study can be viewed as a reduced motivation to feed and forage in the sows (Brouns *et al* 1994) and hence is an improvement in sow welfare.

The treatments had no effect on post-mixing aggression, and this was also reflected in the lack of an effect on aggression-related injury scores. Similarly, a previous study by Whittaker *et al* (1999) found that increasing dietary fibre had no effect on aggression when unfamiliar sows were mixed. Boyle and Gauthier (2004) also found no effect on aggression at mixing when sows were provided with straw in racks or natural fibre ropes. These studies suggest that aggression at mixing is largely unavoidable. In fact, Broom *et al* (1995) suggested that this aggression is necessary to ensure establishment of the dominance hierarchy and to achieve group stability. However, there is evidence that increasing the fibre levels in sow diets and/or providing large amounts of straw can help to reduce levels of chronic aggression, after the initial mixing phase is complete, in group-housed sows (Meunier-Salaün *et al* 2001). Indeed, in the current study, the provision of straw in racks reduced the performance of head thrusting over the course of the four-week experimental period, after the initial mixing period. It is possible that no other effects on aggression were observed as this housing system is generally associated with very low levels of aggression once the dominance hierarchy is formed (Durrell *et al* 1997).

Sows offered the high fibre diet showed a significant reduction in chewing their penmates in the present study. It has been suggested that when feeding motivation is high and the housing environment does not support appropriate consumptive behaviour in pigs, this behaviour may then be redirected towards pen-mates (Haskell *et al* 1996). Chewing penmates is viewed as an adverse or harmful social behaviour (Beattie *et al* 2000), and a reduction in the performance of this behaviour would therefore reflect an improvement in sow welfare. Chewing penmates is normally associated with growing pigs (Beattie *et al* 2000) and is rarely mentioned in sows. The occurrence of the behaviour in the current study may have been due to the presence of primiparous sows in the groups.

Sows offered the high fibre diet spent proportionally more time lying with their eyes closed compared to sows on the control diet, indicating an increase in resting behaviour. Previous studies also found an increase in resting behaviour when fibre levels in the concentrate diet were increased (Matt *et al* 1994; Ramonet *et al* 1999; Stewart *et al* 2007). An increase in resting behaviour is an indication of satiety in sows and may be viewed as a positive welfare indicator (Ramonet *et al* 1999; Zonderland *et al* 2004). Beattie *et al* (1995) suggests that pigs lying inactive with eyes open are alert and this maybe a response to harmful social behaviour therefore the pigs are not resting.

Sows provided with the high fibre diet and access to straw in racks showed increased levels of exploratory behaviour in focal observations. It is possible that the straw racks stimulated exploratory behaviour in the current study. This is in accordance with a study by Durrell *et al* (1997) that showed that providing enriching substrates to sows in small static groups increased the time sows spent exploring their environment. However, the reason why this effect was exacerbated when the high fibre diet was used is not clear. This is in contrast to previous research which showed that increasing the dietary fibre level in the diet reduced exploratory behaviour in sows housed in dynamic group systems (Stewart *et al* 2007).

Sows in the high fibre treatment were heavier than control sows at the end of the treatment period. This may have been due to greater gut fill and an increase in the weight of the gastrointestinal tract arising from the high fibre diet (Brouns *et al* 1995). This is supported by the fact that the heavier weights were not accompanied by greater back-fat depths in the high fibre sows, and therefore did not appear to reflect increased fat deposition. Excessive fat deposition in sows can reduce optimal reproductive performance and increase difficulties in the farrowing house (Dourmad *et al* 1994; Ramonet *et al* 2000b) as well as cause locomotory problems (Meunier-Salaün *et al* 2001). Although results appear positive in the present study, it should be noted that treatment periods were relatively short and therefore the back-fat measurements should be treated with caution.

Conclusion

Both increasing the fibre content of the diet and the provision of straw in racks independently had positive effects on sow welfare in small static groups. Increasing dietary fibre levels promoted resting behaviour and reduced the occurrence of chewing penmates. Providing sows with access to straw in racks led to a reduction in aggressive head thrusting and in stereotypic sham chewing over the treatment period. However a combination of both high fibre diets and the provision of straw in racks led to the greatest reduction in stereotypic behaviour.

Acknowledgements

The authors gratefully acknowledge funding from the Teagasc Walsh Fellowship and DARDNI. We would also like to thank the pig unit staff at Moorepark for their assistance and Dr DJ Kilpatrick and Ms S Dawson for their assistance with statistical analysis.

https://doi.org/10.1017/S0962728600003274 Published online by Cambridge University Press

References

Beattie VE, O'Connell NE, Kilpatrick DJ and Moss BW 2000 Influence of environmental enrichment on welfare-related behavioural and physiological parameters in growing pigs. *Animal Science 70*: 443-450

Beattie VE, Walker N and Sneddon IA 1995 Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare 4*: 207-220

Bergeron R, Bolduc J, Ramonet Y, Meunier-Salaün MC and Robert S 2000 Feeding motivation and stereotypies in pregnant sows fed increasing levels of fibre and/or food. *Applied Animal Behaviour Science 70(1)*: 27-40

Bergeron R, Meunier-Salaün MC and Robert S 2002 Effects of food texture on meal duration and behaviour of sows fed high-fibre or concentrate diets. *Canadian Journal of Animal Science 82*: 587-589

Boyle LA and Gauthier E 2004 Effects of environmental enrichment on the behaviour of sows housed in groups with free-access stall. *Proceedings of the 38th International Congress of the ISAE* pp 144. 3-8 August 2004, Helsinki, Finland

Broom DM, Mendl MT and Zanella AJ 1995 A comparison of the welfare of sows in different housing conditions. *Journal of Animal Science 61*: 369-385

Brouns F and Edwards SA 1994 Social rank and feeding behaviour of group-housed sows fed competitively or *ad libitum. Applied Animal Behaviour Science 39*: 225-235

Brouns F, Edwards SA and English PR 1995 Influence of fibrous feed ingredients on voluntary intake of dry sows. *Animal Feed Science and Technology 54*: 301-313

Council Directive 2001 *Directive 2001/88/EC of 23rd October 2001 amending Directive 91/630/EEC laying down minimum standards for the protection of pigs.* http://www.defra.gov.uk/animalh/welfare/farmed/pigs/

De Leeuw JA, Zonderland JJ, Altena H, Spoolder HAM, Jongbloed AW and Verstegen MWA 2005 Effects of levels and sources of dietary fermentable non-starch polysaccharides on blood glucose stability and behaviour of group-housed pregnant gilts. *Applied Animal Behaviour Science 94(1-2)*: 15-29

Dourmad JY, Etienne M, Prunier A and Noblet J 1994 The effect of energy and protein intake of sows on their longevity: a review. *Livestock Production Science 40*: 87-97

Durrell J, Sneddon IA and Beattie VE 1997 Effects of enrichment and floor type on behaviour of cubicle loose-housed dry sows. *Animal Welfare 6*: 297-308

Haskell MJ, Terlouw EMC, Lawrence AB and Erhard HW 1996 The relationship between food consumption and persistence of post-feeding foraging behaviour in sows. *Applied Animal Behaviour Science 48*: 249-262

Holt JP, Johnston LJ, Baidoo SK and Shurson GC 2006 Effects of a high-fibre diet and frequent feeding on behaviour, reproductive performance, and nutrient digestibility in gestating sows. *Journal of Animal Science 84*: 946-955

Jensen KH, Sørensen LS, Bertelsen D, Pedersen AR, Jørgensen E, Nielsen NP and Vestergaard KS 2000 Management factors affecting activity and aggression in dynamic group housing systems with electronic sow feeding: a field trial. *Animal Science 71*: 535-545

Lawrence AB and Terlouw EMC 1993 A review of behavioural factors involved in the development and continued performance of stereotypic behaviours in pigs. *Journal of Animal Science 71*: 2815-2825

Matte JJ, Robert S, Girard CL, Farmer C and Martineau G-P 1994 Effect of bulky diets based on wheat bran or oat hulls on reproductive performance of sows during their first two parities. *Journal of Animal Science 72*: 1754-1760

McGowan E and McCann MEE 2006 A comparison of pig back-fat measurements using ultrasonic and optical instruments. *Livestock Science 103*: 116-123

Meunier-Salaün MC, Edwards SA and Robert S 2001 Effect of dietary fibre on the behaviour and health of restricted-fed sows. *Animal Feed Science and Technology 90*: 53-69

Ramonet Y, Meunier-Salaün MC and Dourmad JY 1999 High-fibre diets in pregnant sows: digestive utilization and effects on the behaviour of the animals. *Journal of Animal Science 77*: 591-599

Ramonet Y, Robert S, Aumaître A, Dourmad JY and Meunier-Salaün MC 2000a Influence of the nature of dietary fibre on the digestive utilization, some metabolite and hormone profiles and the behaviour of pregnant sows. *Animal Science 70*: 275-286

Ramonet Y, van Milgen J, Dourmad JY, Dubois S, Meunier-Salaün MC and Noblet J 2000b The effect of dietary fibre on energy utilisation and partitioning of heat production over pregnancy in sows. *British Journal of Nutrition 84*: 85-94

Robert S, Bergeron R, Farmer C and Meunier-Salaün MC 2002 Does the number of daily meals affect feeding motivation and behaviour of gilts fed high fibre diets? *Applied Animal Behaviour Science 76*: 105-117

Robert S, Matte JJ, Farmer C, Girard CL and Martineau GP 1993 High fibre diets for sows: effects on stereotypies and adjunctive drinking. *Applied Animal Behaviour Science 37(4)*: 297-309

Scott K, Chennells DJ, Armstrong D, Taylor L, Gill BP and Edwards SA 2007 The welfare of finishing pigs under different housing and feeding systems: liquid versus dry feeding in fully-slatted and straw-based housing. *Animal Welfare 16*: 53-62

Spoolder HAM, Burbidge JA, Edwards SA, Lawrence AB and Simmins PH 1997 Effects of food level on performance and behaviour of sows in a dynamic group housing system with electronic feeding. *Animal Science 65*: 473-482

Stewart CL, O'Connell NE and Boyle LA 2008 Influence of access to straw provided in racks on the welfare of sows in large dynamic groups. *Applied Animal Behaviour Science 112(3-4)*: 235-247

Stewart CL, O'Connell NE, Boyle LA and McCann MEE 2007 The effect of feeding a high fibre diet on the welfare of sows housed in large dynamic groups. *Proceedings of the Agricultural Research Forum 2007* pp 44. 19-21 March 2007, Tullymore, Co Offaly, Ireland

Terlouw EMC and Lawrence AB 1993 Long-term effects of food allowance and housing on development of stereotypies in pigs. *Applied Animal Behaviour Science 38(2)*: 103-126

Tuyttens FAM 2005 The importance of straw for pig and cattle welfare: a review. *Applied Animal Behaviour Science 92*: 261-282

Whittaker X, Edwards SA, Spoolder HAM, Lawrence AB and Corning S 1999 Effects of straw bedding and high fibre diets on the behaviour of floor fed group-housed sows. *Applied Animal Behaviour Science 63*: 25-39

Zonderland JJ, de Leeuw JA, Nolten C and Spoolder HAM 2004 Assessing long-term behavioural effects of feeding motivation in group-housed pregnant sows: what, when and how to observe. *Applied Animal Behaviour Science 87*: 15-30