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Feeding motivation and stereotypies in pregnant sows fed increasing levels of fibre and/or food

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Abstract

Twenty-one multiparous sows were used in a Latin square design, from days 7 to 90 of gestation, to test the effect of fibre and food levels on feeding motivation and feeding-related stereotypies. Treatments were: VHF (very high-fibre, 29% ADF, 50% NDF, 4.5 kg/day); HF (high-fibre, 23% ADF, 43% NDF, 3.5 kg/day); C (control, 8% ADF, 20% NDF, 2.5 kg/day); and control fed ad libitum (CAL). All diets except CAL provided a similar amount of major nutrients on a daily basis and were served in two meals. Each sow was subjected to each treatment for a 21-day period, at the end of which, behavioural observations were made. Two-hour observation periods starting at the afternoon food delivery revealed that sows spent more time eating on VHF and CAL (mean=21.2 min) than on HF (13.2 min) and C (7.6 min) and more time on HF compared to C ($p<0.01$). When time spent eating was removed from total observation time, the percentage of remaining time spent in stereotypies was lower for VHF (median=17.9%) compared to C (median=49.8%), and lower for CAL (median=6.3%) compared to all other diets ($p<0.01$). During the period when lights were on (6.00–18.00 h), 5 min interval scans showed that VHF sows spent more time lying down and less time standing than C sows ($p<0.05$). Also, CAL sows spent more time lying down than sows on other treatments ($p<0.01$). During operant conditioning tests (OCT) performed before the afternoon meal and after the morning meal, less rewards were obtained by CAL sows ($p<0.01$), with no difference between other treatments. In conclusion, no reduction in feeding motivation of sows fed high-fibre diets could be measured by OCT, but very high levels of fibre were effective at reducing stereotypies and activity during the 2 h post-feeding. However, these effects were not as marked as those observed with ad libitum feeding. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Sow-stereotyped behaviour; Feeding; Motivation; High-fibre diet; Operant conditioning

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1. Introduction

Pregnant pigs are routinely restricted-fed and show a high motivation for food after their small daily allowance has been consumed (Lawrence et al., 1988, 1989). The persistence of a high feeding motivation in the post-feeding period is thought to cause the development of stereotypies (Hughes and Duncan, 1988; Lawrence and Terlouw, 1993), which have been described as regularly repeated movements that are morphologically identical and without an obvious function (Ödberg, 1978). In sows, stereotypies often involve feeding-related behaviours (Rushen, 1984, 1985) such as biting and chewing, further supporting a relationship with feeding motivation.

Brouns et al. (1994) suggested that the development of stereotypic behaviour in sows is related to a combination of a lack of sufficient amount of food to promote satiety and to a frustration of foraging and/or feeding behaviour. It has been shown that increasing food allowance (Terlouw et al., 1991) or offering a bulky diet rich in fibrous ingredients, such as beet pulp (Brouns et al., 1994) or oat hulls (Robert et al., 1993), can reduce the performance of stereotypies in sows. The bulk offered by high-fibre diets has the potential to satisfy the sow's motivation for food, without providing her with too much energy. Robert et al. (1997), recently demonstrated that high-fibre diets can significantly reduce feeding motivation of gilts in the short and the longer term, thereby having beneficial effects on their welfare.

The objective of our study was to extend our knowledge of the effect of high-fibre diets on the feeding motivation and behaviour of pregnant sows (fourth parity) by increasing levels of neutral detergent fibre (NDF) and acid detergent fibre (ADF) in their diet, and to better characterise the effects of high-fibre diets by comparing them to a control diet fed in restricted amount or ad libitum.

2. Material and methods

2.1. Animals and housing

Upon breeding, 21 fourth parity sows (Yorkshire X Landrace), weighing on average 200.1 kg, were placed in gestation stalls. Each room contained 70 stalls. The stalls had side divisions made of vertical bars and a top made of four horizontal bars. The floor was partly slatted, the feeder was fixed to the front door and a water bowl with a level-controlled float provided each sow with an ad libitum supply of fresh water. A chain measuring 80 cm and hung from the top of the stall, directly beside the food trough, was provided to each animal as a focal object for stereotypies (Cronin, 1985). Room temperature was kept constant at 18°C and lights were on from 06.00 to 18.00 h. The animals were cared for according to recommended codes of practice (Agriculture and Agri-Food Canada, 1993) and the Canadian Council on Animal Care (1993) guidelines were followed.

2.2. Experimental treatments

Sows were fed concentrate (2.5 kg/day) for the first 6 days after breeding. They were then randomly allocated to one of four treatments, according to a Latin

Table 1
Composition of the gestation diets[a]

	Treatments[a]		
	Very high-fibre (VHF)	High-fibre (HF)	Controls (C and CAL)
Ingredient (g/kg)			
Oat hulls	449.9	265.0	–
Alfalfa meal	281.0	267.7	–
Wheat bran (15.3% CP)	162.0	94.0	149.0
Barley	74.0	100.0	250.0
Corn (7.8% CP)	–	61.0	296.2
Canola meal	–	75.0	100.0
Gluten meal	–	100.0	100.0
Soya meal (47%)	–	–	51.0
Canola oil	12.0	10.0	5.0
Limestone	5.2	8.6	20.7
Salt	3.8	5.1	7.9
Choline	1.1	1.4	1.9
Biotin	1.0	1.1	1.5
L-lysine HCl	1.0	0.3	–
Dicalcium phosphate	6.4	8.8	14.0
Vitamin premix[b]	0.9	1.1	1.7
Mineral premix[c]	0.5	0.7	1.0
Folic acid	0.1	0.1	0.1
Chemical composition			
DE (kcal/kg)	1710.3	2198.0	3080.3
Protein (%)[d]	10.8	13.0	15.1
Lysine (%)	0.5	0.6	0.7
Crude fibre (%)	23.0	18.2	5.3
Ca (%)[d]	1.0	0.9	0.9
P (%)[d]	0.5	0.6	0.8
ADF (%)[d]	28.4	23.5	7.8
NDF (%)[d]	49.4	42.5	20.5

[a] Daily allowances: 4.5, 3.5 and 2.5 kg for VHF, HF and C, respectively.

[b] Provided per kilogram of premix: vitamin A, 7,999,960.0 UI; vitamin D, 1 299,993.5 UI; vitamin E, 34,999.8 UI; vitamin K, 2,722.5 mg; vitamin B12, 17,999.9 μg; riboflavin, 4,499.9 mg; niacin, 25,047.5 mg; folic acid, 509.9 mg; B6 pyridoxine, 2,001.6 mg; thiamin, 1,504.4 mg; pantothenate, 14,167.9 mg; biotin, 49.999.8 μg.

[c] Provided per kilogram of premix: iodine, 2,000.0 mg; cobalt, 495.0 mg; selenium, 300.0 mg; total iron, 82,605.3 mg; total manganese, 54,769.6 mg; total zinc, 126,583.9 mg; total copper, 19,959.9 mg.

[d] Measured values.

square design (Cochran and Cox, 1957). Each treatment was applied to each sow for a period of 21 days, and the experiment lasted until day 90 of gestation. The four experimental treatments consisted of a very high-fibre diet based on oat hulls (VHF: 4.5 kg/day; 7700 kcal of DE), a high-fibre diet based on oat hulls and alfalfa (HF: 3.5 kg/day; 7700 kcal of DE) and a concentrate diet, served either in restricted amount (C: 2.5 kg/day; 7700 kcal of DE) or ad libitum (CAL). Each new diet (Table 1) was introduced gradually, by increasing its proportion in the daily allowance over a period of 4 days. The daily food allowance was also adjusted gradually according to the treatment. Animals received 60% of their daily allowance at 7.30 h and 40% at 14.15 h. CAL sows' feeders were filled every morning. Ad libitum feed intake was measured once for each sow, on day 20 of the ad libitum experimental period.

2.3. Operant conditioning

From days 2 to 6 following breeding, sows were trained to press a red button to receive a food reward. The operant conditioning device was fixed to a gate, which was placed in front of the cage prior to each session. The food reward consisted of 10 g of mash lactation diet (18% CP, 3426 kcal/kg DE). The training was done once a day before the afternoon meal. During a training session, the number of pushes per reward was adjusted according to the learning speed of each animal. The progressive ratio started at one push per reward and was increased to five or 10 pushes per reward in the course of the session. Each training session ended when the sow had obtained 10 rewards.

On day 18 of each 3-week period, prior to each operant conditioning test, sows were resubmitted to a training session for which the first two rewards were each obtained after one push and the next two after five pushes, for a total of four rewards.

2.4. Operant tests of food motivation

On days 20 and 21 of each experimental period, sows were subjected to operant conditioning tests of food motivation. The first test was performed 90 min after presentation of the morning meal on day 20 and the second, 60 min before the afternoon meal on day 21. Before the beginning of each test, any remaining feed in the trough was withdrawn and the operant conditioning device was fixed to the cage. A stop-watch was activated at the time of the first push. The first two rewards were each obtained after one push, and the next two rewards were each obtained after five pushes. The number of times the sows had to push the button to obtain each successive two rewards was then increased by five pushes until the end of the test. Thus, the next two rewards were obtained after 10 pushes, the next two after 15 pushes, and so on up to a maximum of 95 pushes (Robert et al., 1997). The rewards used during the tests were, for technical reasons, slightly different from those used during training, and consisted of 7 g of pelleted lactation diet. At each level of reward, the time of the first push and the time of each reward delivery was recorded. If sows stopped responding for more than six consecutive minutes, the test was ended. Each test lasted a maximum of 60 min and the measure of feed motivation was the number of food rewards obtained during that period.

2.5. Behavioural observations

2.5.1. Observations in the post-feeding period

On day 20 of each 3-week period, continuous behavioural observations were made during the first 2 h after the afternoon food delivery (14.15 to 16.15 h). The observer stood in front of each sow and recorded simultaneously all postural changes (standing, sitting or lying) and activities using a portable data acquisition system (Psion Industry PLC, London, UK). Data were then analysed with a computer program (Observer 4.0, Noldus Information Technology, Sterling, VA). The following mutually exclusive activities were recorded: object-biting (chewing or biting any part of the stall, feeder or water bowl), chain manipulation (chewing, nosing or biting the chain), vacuum-chewing (chewing without any substrate in the mouth), nose-rubbing (ground, feeder, stall bars), head in feeder (when there is no food in the feeder), eating, drinking (manipulating the water bowl), inactive (standing immobile). Any behaviour that did not fall in the above categories was termed ‘other’. Among the activities observed, chain manipulation, vacuum-chewing, nose-rubbing and object-biting were performed repetitively, in a fixed fashion, and corresponded to the description of stereotyped behaviours made in other studies (Fraser, 1975; Rushen, 1984; Robert et al., 1993); therefore, they were considered as such.

2.5.2. Observations over 24 h

The behaviour of sows was video-recorded over a 24 h period by time sampling (30 s of recording every 5 min) to estimate the time spent in various postures (standing, sitting or lying) during a whole day. A camera (Panasonic WV-BL200, Mississauga, Ontario) was mounted from the ceiling above the sow. The 24 h video-recording started at around 16.00 h on day 18. For technical reasons, sows had to be moved to a different stall in order to be filmed. This move took place between 8 and 24 h before the recording started. Direct observations as well as operant testing also took place in this new stall. At the end of the tests, sows were moved back to their home stall, and started their adaptation period to a new treatment.

2.6. Statistical analysis

Data were analysed with the General Linear Model (GLM) procedure of the Statistical Analysis Systems Institute (SAS, 1990), according to the Youden squares method, designed for incomplete Latin squares. Because behavioural data were not normally distributed, they were subjected to a square-root transformation. For the behavioural observations performed in the 2 h period after food delivery, eating duration was subtracted from the total observation time and activities were expressed as a percentage of remaining time. Chain manipulation, vacuum-chewing, nose-rubbing and object-biting were analysed separately as well as in combination (stereotypies). Time spent in various postures was analysed separately over a 12 (06.00–18.00 h) and a 24 h period.

3. Results

3.1. Activities

During the 2 h period following the afternoon food delivery, time spent eating (min) was higher ($p<0.01$) for sows on the VHF (median, SII: 22.2, 7.0) and CAL (18.5, 10.3) treatments, compared to HF (14.0, 4.1) and C (7.3, 2.1) sows. VHF sows spent less time manipulating the chain and object-biting than C sows ($p<0.05$), whereas no differences were observed between VHF and HF, and between HF and C for these behaviours. Vacuum-chewing did not differ between VHF, HF and C treatments. On the other hand, CAL sows spent less time manipulating the chain, object-biting and vacuum-chewing than VHF, HF and C sows ($p<0.05$). When chain manipulation, vacuum-chewing, nose-rubbing and object-biting were combined into one behavioural category (stereotypies), VHF sows spent significantly less time in this category than C sows ($p<0.01$), whereas no differences were observed between treatments VHF and HF, and between HF and C. Time performing stereotypies was higher for VHF, HF and C sows compared to CAL sows ($p<0.01$). Vacuum-chewing, chain manipulation, object-biting and nose-rubbing accounted for 52.7, 32.5, 10.2 and 4.6% of measured stereotypies, respectively. The amount of time (min) spent in overall oral behaviour (feeding and stereotypies) was significantly lower ($p<0.01$) for CAL sows (median, SII: 26.3, 12.5) compared to VHF (41.6, 32.6), HF (46.1, 45.8) and C sows (63.9, 54.3). No differences between treatments were found for nose-rubbing and drinking. C sows spent more time with their head in the feeder than VHF and HF sows ($p<0.05$). VHF sows spent more time inactive than HF and C sows ($p<0.01$), whereas HF sows were more inactive than C sows ($p<0.01$). Finally, CAL sows were more inactive than VHF, HF and C sows ($p<0.01$) (Table 2).

3.2. Postures

Direct observations of sows' postures in the 2 h period after the afternoon food delivery (Table 3) revealed that VHF sows spent more time lying than C sows ($p<0.05$). No other differences between VHF, HF and C treatments were observed, but sows on these treatments spent less time lying than CAL sows ($p<0.01$). Conversely, VHF, HF and C sows did not differ in their time spent standing, but stood more than CAL sows ($p<0.01$). The time spent sitting was not affected by treatments. Posture analysis (Table 4) restricted to the period when lights were on (06.00–18.00 h) revealed that VHF sows spent less time standing ($p<0.05$) and more time lying ($p<0.01$) than C sows. HF sows also spent more time lying than C sows ($p<0.01$). VHF, HF and C sows spent more time standing ($p<0.01$) and less time lying ($p<0.01$) than CAL sows. Time spent sitting was lower for HF compared to C sows ($p<0.05$), and for CAL compared to VHF and C sows ($p<0.01$).

Video-recordings for 24 h (Table 4) revealed that VHF, HF and C sows did not differ in their time spent standing and lying, but spent more time standing ($p<0.01$) and less time lying ($p<0.01$) than CAL sows. Sitting time did not differ between VHF, HF and C sows, but was higher for VHF and C sows, compared to CAL sows ($p<0.01$). No differences were found between HF and CAL for this posture.

3.3. Food consumed by sow on the ad libitum (CAL) treatment

Sows on the CAL treatment consumed on an average 7.2±0.2 kg (average±S.E.) of food. Food consumption decreased linearly ($p<0.05$) over gestation, sows consuming 8.4±1.6, 7.3±0.3, 6.9±0.8 and 6.5±0.2 kg during gestation periods 1 (day 26), 2 (day 47), 3 (day 68) and 4 (day 89), respectively.

Table 2
Effects of dietary treatments[a] on the percentage of time spent in various activities during the 2 h period following the afternoon food delivery[b]

	VHF			HF			C			CAL		
Activity	Median[c]	SII[d]	Max	Median[c]	SII	Max	Median[c]	SII	Max	Median[c]	SII	Max
Chain manipulation	2.9 b	8.0	52.4	3.2 ab	20.5	63.8	5.5 a	35.1	78.0	0.3 c	1.5	15.7
Object-biting	1.0 b	1.9	8.9	1.1 ab	1.8	12.2	2.1 a	3.6	23.2	0.1 c	0.3	2.3
Vacuum-chewing	6.8 a	27.5	80.7	13.3 a	21.7	78.3	9.5 a	40.8	93.8	1.6 b	4.9	64.7
Nose-rubbing	0.2	1.4	4.1	0.3	0.9	7.3	0	1.5	6.8	0.1	1.4	6.2
Stereotypies[e]	17.9 b	39.0	89.5	30.2 ab	51.2	89.9	49.8 a	53.0	95.5	6.3 c	12.7	67.4
Drinking	2.9	2.2	6.8	2.6	4.5	20.4	4.2	5.6	19.1	2.9	2.0	20.2
Head in feeder	1.1 b	1.4	3.6	1.3 b	1.6	3.7	1.9 a	1.5	4.5			
Inactive	43.8 b	55.7	90.9	16.2 c	43.9	89.3	3.5 d	16.9	86.1	78.6 a	34.4	92.9
Other	27.0 a	19.3	56.6	22.8 a	28.8	62.3	23.9 a	33.0	78.8	7.7 b	18.5	41.3

[a] VHF: very high-fibre; HF: high-fibre; C: restricted control; CAL: ad libitum control.
[b] Activities are expressed in percentage of time remaining once feeding time has been removed.
[c] Medians (non-transformed data) within a row without a common letter (a, b, c, d) differ ($p<0.05$).
[d] SII: semi-interquartile interval (q_3-q_1).
[e] Combination of nose-rubbing, chain manipulation, vacuum-chewing and object-biting.

Table 3
Effects of dietary treatments[a] on the total time (min) spent in various postures during the 2 h period following the afternoon food delivery

	VHF			HF			C			CAL		
Posture	Median[b]	SII[c]	Max	Median[b]	SII	Max	Median[b]	SII	Max	Median[b]	SII	Max
Lying	17.7 b	57.6	90.6	1.3 bc	53.9	100.3	0 c	21.9	99.7	80.8 a	21.1	93.9
Sitting	0	38.1	93.9	3.4	39.7	64.3	0.8	44.4	86.8	4.2	21.4	60.5
Standing	67.6 a	64.2	119.9	79.6 a	70.7	119.9	94.5 a	77.1	120.0	31.7 b	14.9	76.4

[a] VHF: very high-fibre; HF: high-fibre; C: restricted control; CAL: ad libitum control.
[b] Medians (non-transformed data) within a row without a common letter (a, b, c, d) differ (p<0.05).
[c] SII: semi-interquartile interval ($q_3 - q_1$).

Table 4
Effect of dietary treatments[a] on the percentage of time spent in various postures[b]

Posture	VHF	HF	C	CAL
06.00–18.00 h[c]				
Lying	51.6 b±4.4	46.2 b±5.0	36.2 c±5.4	75.0 a±1.9
Sitting	11.8 ab±3.0	8.9 bc±2.2	15.0 a±3.9	6.2 c±1.4
Standing	35.2 b±4.5	42.6 ab±5.3	44.8 a±6.3	17.5 c±1.8
24 h				
Lying	70.0 b±3.0	68.2 b±3.4	63.5 b±3.0	83.7 a±2.0
Sitting	6.5 a±1.6	5.3 ab±1.2	7.5 a±1.9	3.5 b±0.8
Standing	21.3 a±2.9	24.7 a±3.5	25.6 a±3.3	10.7 b±1.1

[a] VHF: very high-fibre; HF: high-fibre; C: restricted control; CAL: ad libitum control.

[b] Mean±S.E.; means (non-transformed data) within a row without a common letter (a, b, c, d) differ ($p<0.05$).

[c] Period of time when the lights were on.

3.4. Operant tests of food motivation

During the operant conditioning tests after the morning meal and before the afternoon meal (Table 5), less rewards were obtained by CAL sows compared to sows from other treatments ($p<0.01$). VHF and HF sows did not differ from C sows. Total duration of the tests after the morning meal and before the afternoon meal was shorter for CAL sows compared to VHF, HF and C sows ($p<0.01$). When the 60 min test was divided into 5 min periods, more differences between treatments were observed, but only in the first 5 min period: during that first 5 min period of the test performed after the morning meal, less rewards were obtained for VHF and CAL sows, compared to HF and C sows ($p<0.05$). On the other hand, during the first 5 min period of the test performed before the afternoon meal, less rewards were received by HF sows compared to C sows ($p<0.05$), whereas no differences were found between VHF and HF, and between VHF and C. Also, CAL sows obtained less rewards than sows on any other treatment ($p<0.05$). For subsequent 5 min

Table 5
Effect of dietary treatments[a] on the number of rewards obtained (for test and first 5 min) and on the test duration[b]

		VHF	HF	C	CAL
No. of rewards per test	AM[c]	24.7 a±4.1	22.6 a±3.6	24.2 a±4.3	9.2 b±3.5
	PM[d]	26.3 a±4.2	24.3 a±3.6	25.2 a±4.4	7.3 b±3.1
No. of rewards for first 5 min	AM[c]	5.5 b±0.4	6.5 a±0.4	6.7 a±0.3	4.9 b±0.6
	PM[d]	6.8 ab±0.3	5.9 b±0.3	6.9 a±0.4	4.8 c±0.4
Test duration (min)	AM[c]	51.2 a±6.1	51.6 a±5.3	52.0 a±6.3	20.6 b±6.6
	PM[d]	52.3 a±5.4	54.5 a±3.9	53.9 a±3.7	19.1 b±6.3

[a] VHF: very high-fibre; HF: high-fibre; C: restricted control; CAL: ad libitum control.

[b] Mean±S.E.; means (non-transformed data) within a row without a common letter (a, b, c, d) differ ($p<0.05$).

[c] Test performed 90 min after presentation of the morning meal.

[d] Test performed 60 min before the afternoon meal.

periods of the tests performed before the afternoon meal and after the morning meal, only CAL sows obtained less rewards than sows on other treatments ($p<0.01$).

For the tests performed after the morning meal, the number of rewards obtained by sows was significantly lower ($p<0.05$) at the end of the first period of pregnancy (average number of rewards on day 26±S.E.: 16.9±3.5), compared to the three subsequent periods (average±S.E. on day 47: 21.4±3.1; on day 68: 20.0±4.2; on day 89: 22.4±4.7). When results from the ad libitum treatment were removed from the analysis, this effect was still present and significant ($p<0.05$). The number of rewards obtained by sows for the tests before the afternoon meal (average number of rewards±S.E.: 20.7±1.5) was not affected by gestation period. Similarly, no influence of the stage of pregnancy was found for the total duration of the tests (average duration (min)±S.E.: 43.9±2.6 and 44.9±2.9 for tests after the morning meal and before the afternoon meal, respectively).

4. Discussion

The decreased incidence of chain manipulation and object-biting in the post-feeding period for sows on the VHF treatment is in accordance with the observations of other authors (Robert et al., 1993; Brouns et al., 1994; Robert et al., 1997; Ramonet et al., 1999). Vacuum-chewing was not affected by the fibrous treatments, perhaps because this stereotypy is less easily reversible. Cronin (1985) suggested that over time, stereotypies tend to become more self-directed (i.e. vacuum-chewing), and also less reversible, because they become more strongly integrated in the behavioural repertoire of the animal. Our sows were all in their fourth parity and therefore had the chance to develop self-directed stereotypies long before the start of the experiment. Even though the median showed a reduction in the percentage of time spent performing vacuum-chewing in sows fed ad libitum, some animals were still engaged in this activity for high proportion of observation time (maximum value of 64.7%).

Including a high level of fibre in the sows' diet increased the time spent eating, which has also been observed by previous authors (Mroz et al., 1986; Brouns et al., 1994; Robert et al., 1997; Ramonet et al., 1999; Whittaker et al., 1999). During the 2 h period following the afternoon food distribution, time spent eating for VHF sows was as long as for CAL sows. This effect of fibre on time spent eating was previously associated with its effect on stereotypic behaviours (Robert et al., 1997). An increase in time spent eating could indeed allow the animal to perform more feeding-related behaviours, which would in turn reduce its motivation to perform such behaviours in the form of stereotypies (Lawrence and Terlouw, 1993).

VHF treatment increased the time spent lying down after meal time. This calming effect of fibre in the post-feeding period has also been observed by other authors (Fraser, 1975; Robert et al., 1993; Brouns et al., 1994). The fact that CAL sows showed a strong increase in lying down time at every observation period supports the hypothesis that lying down is a sign of satiety (Robert et al., 1993). Over a longer period of time (06.00–18.00 h), both fibrous treatments increased resting time, which is also in accordance with previous research (Ramonet et al., 1999). The lack of effect of treatment HF in the post-feeding period is in contradiction with the results of Robert et al. (1997) who, when using a fibrous diet of similar composition, found a reduction in stereotypies and an increase in time spent resting in sows. This discrepancy may be due to differences in texture of the food offered. In our experiment, food was offered in pellets instead of mash and the ingestion rate was much higher than in Robert et al.'s (1997) study. Sows fed the HF diet had a food ingestion rate of 106 g/min, whereas sows in Robert et al.'s (1997) study had an ingestion rate of 62 g/min (Robert et al., unpublished data). With such a high ingestion rate, resulting in a shorter time needed to consume the meal, it is likely that sows in our experiment did not perform enough feeding-related behaviours, which would have decreased their stereotypic behaviours and increased their resting time. On the other hand, the positive effects on stereotypic and resting behaviours observed with the VHF treatment may have been due to the lower ingestion rate (79 g/min), which is closer to the rate observed by Robert et al. (unpublished data).

Even though the increased resting time of sows fed fibrous diets could be interpreted as a sign of enhanced satiety (Robert et al., 1993), operant conditioning tests did not reveal any effect of our fibrous treatments on the feeding motivation of sows. This lack of effect of VHF and HF treatments on feeding motivation measured by operant conditioning tests was unexpected given their positive effects on stereotypic behaviours. This is also in disagreement with previous research, which measured a reduction in the number of responses during operant conditioning tests by pigs fed high-fibre diets (Day et al., 1996; Robert et al., 1997). Even though in our experiment, food ingestion rate was lower with high-fibre diets compared to control diet, it is likely that this rate was still too high to reduce feeding motivation in a measurable way by the operant conditioning procedure.

On the other hand, the above discrepancies between our results and previous ones (Robert et al., 1997) may be due to differences in the nature of the reward offered during the operant conditioning tests. We offered a small quantity of a lactation diet as reward, whereas Robert et al. (1997) used the experimental diets as reward. Giving high-fibre rewards may have reduced the number of responses during the operant conditioning tests, simply because the high-fibre rewards may not be as palatable as the rewards made of control diet. Indeed, Kennelly and Aherne (1980) showed that a high level of fibre in the diet may reduce voluntary feed intake because it decreases food palatability. It is therefore possible that in our experiment, sows used to a high-fibre diet and receiving a better tasting reward showed an increased feeding motivation, up to the level of control sows, due to a higher incentive.

Sows on the ad libitum (CAL) treatment, consuming a daily average of 7.2 kg of food, showed a more substantial decrease in stereotypies than sows on the high-fibre treatments, and showed evidence of a reduced feeding motivation during the operant conditioning tests. These results suggest that hunger in VHF and HF sows was not completely satisfied. Brouns et al. (1995) obtained a voluntary feed intake of pigs of 7.7 kg/day when feeding ad libitum a diet containing a high proportion of oat hulls (36.9%, 14.9% ADF and 36.1% NDF. In our experiment, feed intake was limited to 4.5 and 3.5 kg for VHF and HF treatments, respectively. Although the daily allowances provided sows with an adequate amount of energy for maintenance and production, it is possible that they did not provide them with enough bulk to achieve complete satiety.

Regardless of treatment, our sows received a smaller number of rewards than sows of Robert et al.'s (1997) study, even though the reward used was seemingly more palatable.

This was also observed by Ramonet et al. (2000), who measured feeding motivation in multiparous sows fed concentrate and high-fibre (wheat bran and sugar beet pulp) isoenergetic diets. Even though it has been argued that sows may have a lower feeding motivation than gilts (see Ramonet et al., 2000), it is also possible that older animals (multiparous) are less capable of performing the operant conditioning tests effectively, compared to younger animals (gilts). Sows may need to make a greater effort to push the button, or they may have difficulties in learning the testing procedure. Goodrick (1975) observed a similar phenomenon in mice. Older mice had a lower rate of responding than younger mice in operant conditioning tests. Furthermore, Goodrick (1968) reported that adult rats were more likely to repeat mistakes that had been developed while learning to find their way in a maze, while younger rats did not make repetitive mistakes. It is therefore possible that, because of a reduced ability, older sows reach a ceiling, preventing them to respond faster despite their motivation. Lawrence et al. (1988) reported the existence of a ceiling effect during operant conditioning tests, which in their case was not due to age, but perhaps to other factors such as the motivational system or the experimental procedure.

Although the feeding motivation measured by the operant conditioning tests was not reduced by our high-fibre treatments, it seems to have been affected by the gestation period. Sows were less motivated in the post-feeding period at the beginning of pregnancy (day 7–27), compared to other gestation periods. Since this effect was still present when CAL sows were removed from the analysis, it was not only due to the increased feed intake of CAL sows during the first period of pregnancy. Even though no further increase in feeding motivation was observed from day 28 to 90 of gestation, this is consistent with the finding that the incidence of stereotypic behaviours increases over the course of pregnancy (Cronin, 1985; Bergeron and Gonyou, 1997).

5. Conclusion

Adding a large quantity of fibre in diets for pregnant sows decreases stereotypies and prolongs resting time. These effects seem to be associated with time spent eating and they indicate that high-fibre diets promote satiety. However, high-fibre diets did not reduce feeding motivation measured by operant conditioning tests. This lack of effect could be explained by the older age of the sows used in our experiment, compared to previous experiments in which gilts were used. It could also be due to the fact that time spent eating may not have been long enough to completely satisfy feeding motivation. In fact, the ad libitum treatment was the only one to affect feeding motivation. Nevertheless, high-fibre diets have positive effects on animal welfare, which could be enhanced by prolonging meal time even further. This could be achieved by serving a mash instead of a pelleted diet or by a greater inclusion rate of fibre.

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