RESEARCH REPORT
ANIMAL WELFARE

Title: Enhancing Sow Welfare with High Fiber Diets and Frequent Feeding - **NPB #02-158**

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Abstract: A study was conducted to determine the effects of feeding a corn-soybean meal (control) diet vs. a corn-soybean meal-soybean hulls (high fiber) diet and feeding frequency (once vs. twice daily) on the welfare of gestating sows. Two hundred thirty-nine mixed parity sows were assigned to a 2 x 2 factorial arrangement of treatments. Daily feed allowances were calculated to provide equal ME intake between dietary treatments. Sows fed once daily received their entire meal at 0730 h while sows fed twice daily received one half their allotment of feed at 0730 h and the other half at 1430 h. Behavior of 67 focal sows was observed on the day of weaning, day 40, and day 80 of gestation. Percentage of time standing, lying, sitting, feeding, inactive, and performing stereotypic behaviors was determined. Saliva samples were collected to determine cortisol concentration. Sow weight and backfat depth were determined on day 0, day 40 and day 80 of gestation, within 24 h of farrowing and at weaning. Litter size and piglet weight at birth and weaning were also recorded.

Sows fed the high fiber diet spent more time standing and less time lying ($P < .05$) than sows fed the control diet over a 24 h observation period. Feeding frequency had no effect on sow behavior measured over a 24 h period. Around mealtimes, sows fed the high fiber diet spent more time feeding ($P < .05$) than sows fed the control diet. Feeding the high fiber diet had no effect on stereotypic behavior measured over 24 h or around mealtimes. Neither diet nor feeding frequency affected salivary cortisol concentration. Sows fed the high fiber diet were lighter and had less backfat ($P < .05$) during gestation than sows fed the control diet. Similarly, during gestation, sows fed once daily were lighter and had less backfat ($P < .05$) than sows fed twice daily. Sows fed the high fiber diet had fewer pigs born ($P < .05$) compared to sows fed the control diet; however, litter size at weaning was not different between diets. Feeding frequency had no effect on litter size or weight gain. Feeding a high fiber diet utilizing soybean hulls did not enhance the welfare of sows by reducing stereotypic behaviors, influencing salivary cortisol, or improving reproductive performance. Soybean hulls may not be a useful source of fiber in gestating sow diets to improve litter size.

Introduction: Modern, confinement pork production systems are under increasing societal pressure to change the methods used to house and care for pigs. The recent interest of McDonalds and other fast food giants in poultry and swine production practices provides clear evidence that society is and will continue to influence the way meat animals are produced in the U.S. Of particular concern for the public is the welfare of pregnant sows in modern, confinement pork production systems. Pregnant sows housed individually in stalls and fed limited amounts of feed to control weight gain typically develop stereotypic behaviors (Robert et al., 1997) which are perceived as an outward sign of compromised sow welfare by the general public. Concerned citizens suggest two obvious solutions that are perceived to improve the welfare of pregnant sows: 1. remove gestation stalls and house sows in large groups and 2. feed sows a greater quantity of feed. Unfortunately, these apparently simplistic solutions have many negative ramifications for sows and pork producers.

Changing the housing system for sows cannot be accomplished in the near term due to high cost of retrofitting barns and our lack of understanding large group housing systems in the U.S. In contrast, dietary manipulations to allow increased feeding levels and improvements in satiety of sows could be implemented in existing confinement housing systems. Feeding confined gilts less than 4.5 lb of feed dramatically increased stereotypic behaviors (Appleby and Lawrence, 1987). Furthermore, increasing feed allowance led to an increase in time that gilts spent lying which presumably indicates gilts were more satisfied and experienced less hunger. Several researchers have demonstrated that feeding diets high in fiber decrease the incidence of stereotypic behaviors (Robert et al., 1997; Bergeron et al., 2000) and presumably improve the welfare of gestating sows. Unfortunately, diets used in these experiments were based on very high levels of ground corn cobs, wheat bran, oats, and oat hulls. These experimental diets would not flow through feed handling and delivery systems typically used in most confinement production units. In addition, these ingredients are not readily available to most U.S. pork producers. Consequently, the diets used to demonstrate reductions in stereotypic behavior are not adaptable to U.S. production conditions and will not be used to improve welfare of sows. McGlone and Fullwood (2001) eased the handling problems associated with high fiber inclusion levels by pelleting a diet that contained 25% beet pulp. They reported no reduction in stereotypic behaviors of gestating gilts. The pelleting process may have altered the character of the dietary fiber and rendered it ineffective in reducing stereotypic behaviors.

Soy hulls are high in total dietary fiber and are readily available to U.S. pork producers. In addition, diets containing relatively high levels of soy hulls (30 to 40%) will flow through typical feed handling and distribution systems without pelleting the diet. Soy hulls have the advantage of greater digestibility compared to other fiber sources which will decrease solid buildup in and clogging of liquid manure handling systems. Less digestible fiber sources wreak havoc with liquid manure systems. From a sow welfare perspective, the relatively high digestibility of soy hulls may be a disadvantage because there is a smaller "bulking" effect in the gut compared with other fiber sources. We are unaware of any research that evaluated the effects of a commercially adaptable fiber source such as soy hulls on stereotypic behavior and welfare of gestating sows.

Increasing the number of daily meals for gestating sows should improve welfare of sows because stereotypic behaviors could be directed to a natural, productive activity such as eating. Intuitively, this approach makes sense. However, Robert et al. (2002) reported that sows fed two meals per day spent more time engaged in stereotypic behaviors and less time lying down compared with sows fed once daily during the 45 minutes following the second meal. These researchers only assessed sow welfare in

the 2 hours around the morning and afternoon meals which did not provide a complete evaluation. Sow welfare is a concern 24 hours per day.

Objectives:

1. To evaluate the efficacy of a high fiber diet based on corn, soybean meal, and soy hulls to decrease the occurrence of stereotypic behaviors and improve welfare of gestating sows housed in individual stalls.

2. To determine the effects of feeding frequency on welfare of individually housed sows around feeding and throughout the day.

3. To quantify the interactive effects of a high fiber diet and feeding frequency on sow welfare and performance.

Materials and Methods: *Animal Management.* The experimental protocols used in this study were approved by the University of Minnesota Institutional Animal Care and Use Committee. The study was conducted at the Southern Research and Outreach Center located in Waseca, MN. Two hundred thirty-nine mixed parity sows (GAP genetics, Landmark, MB, Canada) were used to study the main effects of gestation diet and feeding frequency in a 2 x 2 factorial arrangement of treatments. Sows were assigned to treatments based on parity and breeding date. All sows had produced at least one litter before being assigned to experimental treatments and were housed in gestation stalls equipped with an automatic feeder using feed drops. Sows had unlimited access to water from nipple drinkers. Target room temperature was set at 20 ^{o}C (68° F).

Experimental Treatments. The dietary treatments consisted of a corn/soybean meal based diet (control) and a high fiber diet containing soybean hulls as a fiber source (Table 1). Frequency treatments consisted of feeding sows once or twice daily. The two experimental diets were fed from one day after weaning until day 109 of gestation. Diets were formulated to meet or exceed NRC (1998) nutrient requirement recommendations for gestating sows. NRC (1998) suggested the daily energy requirement for gestating sows to be 6,200 kcal ME/day. To provide a daily energy intake of 6,200 kcal/ME per day, sows fed the control diet were initially offered 1.88 kg (4.14 lb) feed per day while sows fed the high fiber diet were offered 2.19 kg (4.82 lb) feed per day. Quantity of feed offered to sows in all treatment groups was adjusted at day 40 and day 80 of gestation, if necessary, based on sow body condition. Body condition scores were subjectively evaluated using a target score of 3, which is approximately 17.8-20.3 mm (.70 to .80 in.) backfat at the last rib (van Heugten, 2000). Changes in the amount of feed offered during gestation were recorded.

Table 1. Composition and nutrient analysis of experimental diets.

Ingredient (%)	Control	High Fiber	Lactation
Corn	80.34	47.29	67.05
Soybean hull	---	40.00	---
Soybean meal (46%)	14.00	7.75	25.00
Tallow	1.00	1.00	4.00
Dicalcium phosphate (18.5%)	2.50	2.45	2.00
Calcium carbonate	1.00	0.35	0.95
Salt	0.35	0.35	0.35
Vit./min. premix[a]	0.25	0.25	0.25
Tylan 40	0.05	0.05	---
L-Lysine HCl	---	---	0.10
Biotin	0.30	0.30	0.30
Choline chloride	0.21	0.21	---
TOTAL	100.00	100.00	100.00
Calculated Analysis:			
ME, Mcal/kg	3.30	2.84	3.41
Crude protein, %	13.7	12.5	16.8
Lysine, %	.61	.60	.97
Ca, %	.98	.88	1.1
P, %	.77	.71	.71
Lab Analysis:			
Crude protein, %	12.75	12.42	
Ca, %	.92	.79	
P, %	.65	.49	

[a] Premix supplied the following per kg of diet: Zn, 120 mg; Mn, 12 mg; Fe, 150 mg; Cu, 12 mg; Se, 1 mg; niacin, 45 mg; calcium pantothenate, 24 mg; Vit. A, 500 IU; Vit. E, 22 IU; riboflavin, 12 IU; Vit. B_{12}, 30 μg; biotin, 200 μg; choline chloride, 840 mg.

Sows fed once daily received their entire allotment of feed at 0730 h, while sows fed twice daily received one half of their allotment at 0730 h and the other half at 1430 h. Sows fed twice daily were housed in a room separate from sows fed once daily so that the second feeding did not influence the behavior and activity of sows fed only once daily. During lactation, all sows were provided *ad libitum* access to a common diet in meal form (Table 1).

Behavior Determinations. A minimum of fifteen sows per treatment combination was selected to serve as focal sows. The focal sows (n = 67) were observed using time-lapse video recording for 24 h on the day of weaning, day 40 and day 80 of gestation. Videos were scored 20 minutes per h for 24 h using four intervals of five minutes throughout each h (e.g. 12:00-12:05, 12:15-12:20 h). Behaviors evaluated included postures and activities. Postures measured included duration of time spent lying, sitting, or standing. Activities recorded included feeding, sham chewing, bar biting, and nosing the feeder or floor. Sham chewing, bar biting, and nosing the floor and feeder were added together to form one category of stereotypic behaviors. Due to the placement of the video camera, it was not possible to recognize feed in the feeder, but it was clear when feed dropped into the feeder. Therefore, after the feed was dropped, a sow was considered to be feeding from the time her head was observed in

the feeder until the sow moved at least one whole step back from the feeder.

Stress Physiology Measurements. Saliva was collected from focal sows on the day after weaning, and on day 42, and day 82 of gestation using a salivette with a cotton swab (SARSTEDT, Aktiengesellschaft and Co., Numbrecht, Germany), which was attached to a length of wire. Samples were taken at approximately 1300 h each collection day. Swabs were centrifuged at 2000 rpm for five min to extract the saliva. Saliva was frozen at –20□ C (-4 °F) immediately after collection until cortisol analysis could be conducted. Saliva samples were analyzed for cortisol concentration using a radioimmunoassay technique (Coat-a-Count TKCO, Diagnostic Products Corporation, Los Angeles, USA) as described by Deen et al. (2004).

Performance Measurements. Sow performance measurements were recorded during gestation and the subsequent lactation. Sows were weighed and backfat measurements were recorded on day 0 (breeding), day 40 and day 80 of gestation, within 24 h of farrowing, and at weaning. Backfat was measured at the last rib using ultrasound (Renco Corporation, Minneapolis, MN). After farrowing, litter size at birth and weaning were recorded. Litter size was equalized within diet and frequency treatments to achieve a target of 9 to 10 pigs per litter. Sows were fed twice daily during lactation to ensure *ad libitum* access to feed. Feed not consumed was weighed on day 7 and day 14 of lactation, and at weaning, and was subtracted from the total amount of feed offered to determine feed disappearance for each time period.

Statistical Analysis. Data were analyzed by least squares analysis of variance using the General Linear Models procedure of SAS (SAS Inst. Inc., Cary, NC). Repeated measures in time were used to analyze sow behaviors, salivary cortisol concentration, sow body weight and backfat depth, and litter performance. The initial statistical model included the effects of diet, feeding frequency, parity group, farrowing group, and all possible interactions. Parity group 1 described sows in parities 1 or 2, while parity group 2 described sows in parity 3 and higher. Whenever the two, three, and four factor interactions were not significant ($P > .05$), these factors were pooled into the residual error term. However, interactions with time and the two-factor interaction of diet and feeding frequency remained in the model regardless of level of significance.

Results: *Sow behavior.* Over a 24 h observation period, sows fed the high fiber diet behaved differently ($P < .05$) compared to sows fed the control diet at different stages of gestation (Table 2). At weaning, there were no differences in any measurement of postures or activities of sows within dietary or feeding frequency treatment. On day 40 and day 80 of gestation, fiber-fed sows spent a greater percentage of time sitting and a smaller percentage of time lying over a 24 h observation period compared to control-fed sows ($P < .05$). Stereotypic behaviors and percentage of non-active time measured over a 24 h observation period on day 40 and day 80 of gestation were not affected by dietary treatment. Feeding sows once or twice daily had no effect on postures or non-eating behaviors measured over a 24 h observation period at weaning, d 40, and d 80 of gestation (Table 2). However, at d 40 and d 80 of gestation, sows fed twice daily spent a higher percentage of time feeding ($P < .05$) than sows fed once daily.

At day 40 and day 80 of gestation, diet had no effect on postures of sows measured around feeding time (Table 3). During the 3 h feeding period (one hour before plus 2 hours after feed was dropped), fiber-fed sows spent a greater percentage of time eating compared to control sows ($P < .05$). Feeding frequency affected ($P < .01$) postures of gestating sows when measured around mealtimes. At d 40 and d 80 of gestation, sows fed once per day spent a greater percentage of time standing and a lower percentage of time lying around mealtimes compared to sows fed twice per day.

Table 2. Effects of experimental diet and feeding frequency on the 24-h behavior pattern of sows at three stages of gestation (% of observation time).

	Diet			Frequency		
Criteria	**Control**	**High Fiber**	**PSEM**	**1X**	**2X**	**PSEM**
No. of sows	34	33		34	33	
			Weaning			
Posture:						
Lying	76.8	72.4	1.90	74.2	74.9	1.90
Sitting	5.3	5.3	0.77	5.2	5.5	0.77
Standing	17.9	22.3	1.74	20.6	19.6	1.74
Activity:						
Feeding	1.6	1.7	0.12	1.5	1.8	0.12
Stereotypic	17.5	21.5	1.70	20.5	18.6	1.70
Non-active	80.9	76.8	1.71	78.0	79.6	1.71
			Day 40			
Posture:						
Lying	73.1[a]	67.5[b]	1.58	69.1	71.6	1.58
Sitting	1.0[a]	4.0[b]	0.72	2.6	2.6	0.72
Standing	25.9	28.5	1.71	28.3	25.8	1.71
Activity:						
Feeding	2.4[a]	2.9[b]	0.18	2.4[a]	3.0[b]	0.18
Stereotypic	24.1	26.6	1.62	27.2	23.5	1.62
Non-active	73.5	70.5	1.67	70.4	73.5	1.67
			Day 80			
Posture:						
Lying	78.1[a]	72.4[b]	1.51	74.9	75.6	1.51
Sitting	1.6[a]	5.3[b]	0.99	3.4	3.4	0.99
Standing	20.3	22.3	1.53	21.7	21.0	1.53
Activity:						
Feeding	2.4[a]	3.1[b]	0.12	2.5[a]	3.0[b]	0.12
Stereotypic	18.6	20.4	1.49	20.6	18.4	1.49
Non-active	79.0	76.5	1.50	76.9	78.6	1.50

[a,b] Means are different within main effect ($P < .05$).

Table 3. Effects of feeding a high fiber diet and frequent feeding on the behavior pattern of gestating sows around feeding time* (% of observation time).

	Diet			Frequency**		
Criteria	**Control**	**High Fiber**	**PSEM**	**1X**	**2X**	**PSEM**
No. of sows	34	33		34	33	
			Weaning			
Posture:						
Lying	50.0	47.9	3.60	43.7	54.3	3.60
Sitting	7.0	6.2	1.53	7.0	6.7	1.53
Standing	43.0	45.9	3.59	49.3	39.0	3.59
Activity:						
Feeding	9.0	10.2	0.58	13.0[a]	6.9[b]	0.58
Stereotypic	34.0	37.3	3.27	38.0	32.9	3.27
Non-active	57.0	52.5	3.39	49.0	60.2	3.39
			Day 40			
Posture:						
Lying	24.0	17.2	2.53	11.8[a]	29. 0[b]	2.53
Sitting	1.0	5.2	1.28	2.4	4.0	1.28
Standing	75.0	77.6	2.66	85.8[a]	67.0[b]	2.66
Activity:						
Feeding	13.3[a]	17.2[b]	1.10	18.6[a]	11.8[b]	1.10
Stereotypic	61.8	61.4	2.70	67.6[a]	55.6[b]	2.70
Non-active	24.9	21.4	2.67	13.8[a]	32.6[b]	2.67
			Day 80			
Posture:						
Lying	35.1	31.4	2.73	25.0[a]	42.0[b]	2.73
Sitting	3.3	8.4	1.82	6.0	6.0	1.82
Standing	60.6	60.2	2.73	69.0[a]	52.0[b]	2.73
Activity:						
Feeding	13.2[a]	18.1[b]	0.76	19.7[a]	11.6[b]	0.76
Stereotypic	48.4	43.8	2.54	50.8[a]	41.4[b]	2.54
Non-active	38.4	38.1	2.65	29.5[a]	47.0[b]	2.65

* Observation time was one hour before plus 2 hours after feed was dropped.
** Three hours of observation time for 1X and six hours of observation time for 2X daily.
[a,b] Means are different within main effect ($P < .05$).

Stress physiology. Feeding a high fiber diet to gestating sows had no effect (P > .05) on salivary cortisol concentration (Figure 1). Feeding sows once or twice daily also had no effect (P > .05) on salivary cortisol concentration (Figure 2). There was, however, a highly significant time effect (P < .01) on cortisol concentration observed for both diet and feeding frequency treatments. Regardless of treatment, cortisol concentration was highest at weaning and decreased throughout gestation.

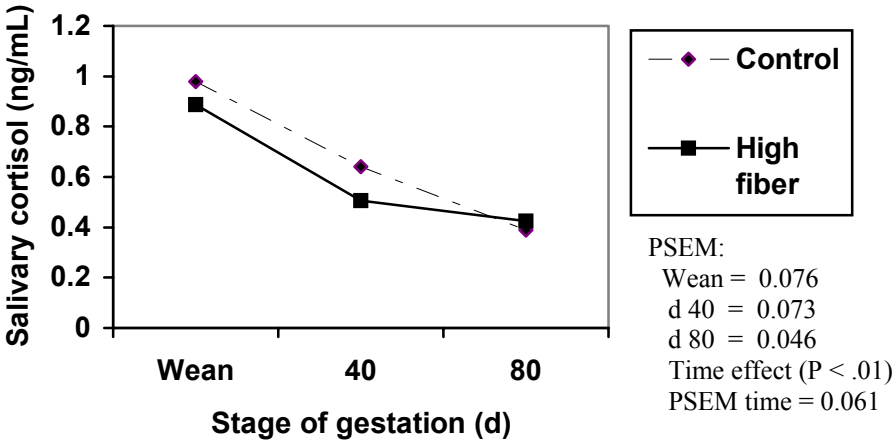

Figure 1. Effect of dietary treatment on salivary cortisol concentration.

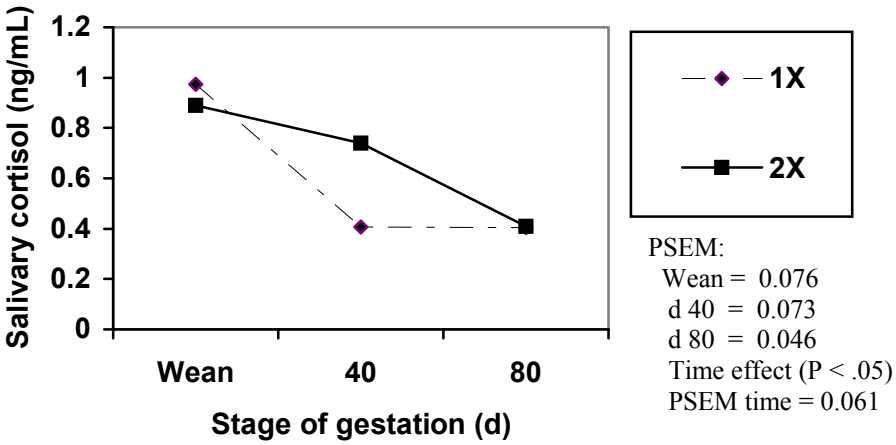

Figure 2. Effect of feeding frequency on salivary cortisol concentration.

Sow performance. Dietary treatment affected the performance of sows (Table 4). Sows fed the control and high fiber diets had similar weights at breeding and day 40 of gestation, but by day 80 of gestation, sows fed the high fiber diet weighed less than sows fed the control diet (P < .01). This difference in sow body weight was maintained throughout the remainder of the gestation and lactation periods. Sow backfat depth was similar at breeding, but by day 40 of gestation, sows fed the high fiber diet had less backfat (P < .05) compared to sows fed the control diet. This difference in backfat thickness was also maintained throughout the remainder of the gestation period and subsequent lactation.

Table 4. Effects of diet and feeding frequency on sow weight gain, backfat depth, lactation length, feed intake, and wean-to-estrus interval.

	Diet			Frequency		
Criteria	Control	High Fiber	PSEM	1X	2X	PSEM
No. of sows	122	117		116	123	
Sow weights (kg):						
Breeding	194.1	190.5	1.51	190.6	194.0	1.51
d 40	199.0	195.5	1.45	193.8[a]	200.7[b]	1.45
d 80	213.5[a]	206.9[b]	1.43	205.3[a]	215.1[b]	1.43
d 109	228.2[a]	220.4[b]	1.54	218.3[a]	230.1[b]	1.54
24 hr post-farrowing	213.2[a]	204.8[b]	1.52	202.9[a]	215.1[b]	1.52
weaning	218.6[c]	212.3[d]	1.77	210.6[a]	220.6[b]	1.77
Sow backfat depth (mm):						
Breeding	16.9	16.5	0.391	16.2	17.1	0.391
d 40	17.0[c]	15.5[d]	0.418	15.8	16.7	0.418
d 80	17.6[a]	15.7[b]	0.438	15.9[c]	17.4[d]	0.438
d 109	17.2[a]	15.5[b]	0.397	15.5[a]	17.2[b]	0.397
24 h post-farrowing	16.4[a]	14.7[b]	0.380	14.7[a]	16.4[b]	0.380
weaning	15.4[c]	14.2[d]	0.362	14.0[a]	15.6[b]	0.362
Lactation length (days)	18.4	18.1	0.116	18.1	18.4	0.117
Lactation feed intake (kg/d)	7.4	7.5	0.107	7.6	7.3	0.107
Wean-to-estrus interval (days)	4.5	4.6	0.056	4.5	4.6	0.056

[a,b] Means different within main effect (P < .01).
[c,d] Means different within main effect (P < .05).

There were no differences in lactation length, average daily feed intake during lactation, or wean-to-estrus intervals for sows fed the high fiber diet compared to sows fed the control diet.

Feeding frequency also affected sow performance (Table 4). Sow weight was similar at breeding, but on day 40 of gestation, sows fed twice daily weighed more than sows fed once daily (P < .05). This difference was maintained throughout the remainder of gestation and throughout lactation. At breeding and day 40 of gestation, backfat depth was similar between once daily and twice daily treatment groups. By day 80 of gestation, backfat depth was lower for sows fed once daily (P < .05), and this difference was maintained throughout the remainder of gestation and the subsequent lactation period. Lactation length, lactation feed intake and wean-to-estrus interval were not affected by feeding frequency.

Litter Performance. Sows fed the control diet had increased total pigs born, pigs born alive, and 24 h litter size (P < .05) compared to sows fed the high fiber diet (Table 5). There was no effect of diet (P > .05) on litter weight at birth, 24 h, and weaning or average piglet weight at birth, 24 h, and weaning. Feeding frequency had no affect (P > .05) on any litter performance measurements.

Table 5. Effects of diet and feeding frequency on litter performance.

	Diet			Frequency		
Criteria	Control	High Fiber	PSEM	1X	2X	PSEM
No. of sows	122	117		116	123	
Litter size:						
Total born	11.7[a]	10.8[b]	0.252	11.2	11.2	0.252
Born alive	10.7[a]	9.8[b]	0.252	10.2	10.2	0.252
After cross-foster	10.9[a]	10.5[b]	0.088	10.6	10.9	0.088
Pigs weaned	9.7	9.9	0.071	9.8	9.8	0.071
Litter weight (kg):						
Birth	16.3	14.8	0.343	15.3	15.7	0.344
After cross-foster	16.6	16.2	0.215	15.9	16.8	0.215
Wean	62.5	62.7	0.807	61.8	63.4	0.807
Avg. pig birth weight (kg)	1.5	1.5	0.020	1.5	1.6	0.020
Avg. pig wean weight (kg)	6.4	6.4	0.067	6.3	6.4	0.067

[a,b] Means different within main effect ($P < .05$).

Discussion: The main effects of diet composition and feeding frequency did not interact to influence any of the response criteria evaluated in this experiment. This lack of interaction suggests that the effects of diet composition and feeding frequency worked independently to influence the response criteria.

Previous research with high fiber diets suggested that our high-fiber diet might elicit an improvement in sow welfare as indicated by decreased stereotypic behaviors and salivary cortisol concentration, and an improvement in reproductive performance of sows. In this experiment, feeding the high fiber diet increased feeding time similar to that reported in other studies. The increased feeding time significantly reduced the proportion of time sows spent lying. Often, reduced time spent lying might be equated to compromised welfare of sows. But in this case, reallocation of time spent lying to feeding would not seem negative to welfare of sows. Increasing dietary fiber did not reduce the amount of time sows engaged in stereotypic behaviors in contrast to results reported by Robert et al. (1997) and Ramonet et al. (1999). Similarly, the high fiber diet did not have any influence on salivary cortisol concentration of sows at any time during the experiment. These two observations taken together suggest that the inclusion of 40% soy hulls in diets has no effect on welfare of gestating sows. While this diet was adaptable to feed delivery systems commonly used in the U.S., it did not have any apparent beneficial effects on sow welfare. Possibly, the composition and physical characteristics of the fiber used in this experiment was not suitable for reduction in stereotypic behaviors and improved welfare of sows. Others (Whittaker et al., 1998; McGlone and Fullwood, 2001) reported no differences in stereotypic behavior when sows were fed high fiber diets compared to sows fed control diets and suggested that a low amount of nutrient intake and diet palatability were the reasons for lack of treatment effects.

Cariolet and Dantzer (1984) found that body condition had significant effects on time spent standing and activity of sows. Sows with a body condition score of 3 (ideal) spent more time standing than sows with a body condition score of 5 (over-conditioned), and thin sows tended to be hyperactive (Cariolet and Dantzer, 1984). In the present study, the target subjective body condition score was 3. Over half of the sows receiving the high fiber diet received increases in daily feed allowance during the study, which meant these sows would have had body condition scores less than 3. This may have increased the stereotypic behaviors for these sows and may explain why no differences in stereotypic behaviors were observed between dietary treatments.

Offering feed to sows twice per day compared to once per day did not have any appreciable effect on sow welfare or performance. Twice daily feeding reduced the proportion of time around feeding that sows engaged in stereotypic behaviors. Because there were two feeding periods each day for sows assigned to the 2X treatment, the total time spent in stereotypic behaviors around feeding was increased by twice daily feeding (day 40, 3.34 vs 2.03 h; day 80, 2.48 vs 1.52 h for 2X vs 1X, respectively). However, there was no difference in the proportion or the absolute amount of time sows spent engaged in stereotypic behaviors over a 24 hour day.

Several researchers (Hagen, 1988; Ewan et al., 1996; Greishop et al., 2001) have reported increases in litter size attributable to feeding high fiber diets during gestation. However, this response is variable. Nelson et al. (1992) reported an increase in litter size when sows received a gestation diet containing wheat straw but a numerical depression in litter size when contemporary sows received diets containing high levels of soy hulls. Similarly, Renteria (2003) found no improvement in litter size when sows received a diet high in soy hulls beginning after mating until farrowing. Possibly, soy hulls do not offer the appropriate chemical or physical properties to elicit a beneficial response in litter size.

Feeding frequency had no significant effects on litter size or performance. This observation agrees with results reported by Wittman (1986) where no differences in number of pigs born, pigs born alive, pigs weaned, or piglet birth and weaning weights were observed when sows were fed either once or twice daily during gestation.

Take home points for pork producers–

1. Corn-soybean meal based diets containing up to 40% soybean hulls can flow through commercial feed delivery systems with minimal or no bridging problems. However, the upper limit of soy hull inclusion may differ slightly among feed systems and soy hull sources.

2. Inclusion of 40% soybean hulls in corn-soybean meal diets fed at typical industry levels to gestating sows seem to have no benefits related to sow welfare and reproductive performance.

3. There appears to be no benefit of feeding sows twice daily compared to once daily feeding.

Lay Interpretation: In this experiment, we attempted to employ a diet and feeding regimen that could be easily implemented in commercial production units while improving welfare as measured by occurrence of stereotypic behaviors and salivary cortisol and performance of sows. We chose soy hulls as our fiber source because they are readily available to U.S. pork producers at a reasonable price and diets containing high levels of soy hulls will flow readily through commercial feed delivery systems.

Unfortunately, our approach did not improve welfare or performance of sows. We surmise two possible reasons for this lack of beneficial effects. First, the total quantity of feed offered to sows may have been too small to positively affect sow welfare. The quantities offered in our experiment are typical of feeding levels used in commercial pork production. This quantity of feed may be sufficient to satisfy the sows' nutrient needs for acceptable reproductive performance but insufficient to satisfy her physical needs for acceptable welfare. In the future, there may be a feeding level for acceptable reproductive performance and a different feeding level for acceptable sow welfare. Second, while soy hulls are easy to acquire and use in commercial applications, they appear to lack the necessary chemical and(or) physical characteristics to improve sow welfare and performance.

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TABLES WITH ENGLISH UNITS FOR RESPONSE VARIABLES.

Table 4. Effects of diet and feeding frequency on sow weight gain, backfat depth, lactation length, feed intake, and wean-to-estrus interval.

	Diet			Frequency		
Criteria	**Control**	**High Fiber**	**PSEM**	**1X**	**2X**	**PSEM**
No. of sows	122	117		116	123	
Sow weights (lb):						
Breeding	427.9	420.0		420.2	427.7	
40	438.7	431.0		427.2[a]	442.5[b]	
d 80	470.7[a]	456.1[b]		452.6[a]	474.2[b]	
d 109	503.1[a]	485.9[b]		481.3[a]	507.3[b]	
24 hr post-farrowing	470.0[a]	451.5[b]		447.3[a]	474.2[b]	
weaning	481.9[c]	468.0[d]		464.3[a]	486.3[b]	
Sow backfat depth (in):						
Breeding	.66	.65		.64	.67	
d 40	.67[c]	.61[d]		.62	.66	
d 80	.69[a]	.62[b]		.63[c]	.68[d]	
d 109	.68[a]	.61[b]		.61[a]	.68[b]	
24 h post-farrowing	.64[a]	.58[b]		.58[a]	.64[b]	
weaning	.61[c]	.56[d]		.55[a]	.61[b]	
Lactation length (days)	18.4	18.1	0.116	18.1	18.4	0.117
Lactation feed intake (lb/d)	16.3	16.5		16.7	16.1	
Wean-to-estrus interval (days)	4.5	4.6	0.056	4.5	4.6	0.056

[a,b] Means different within main effect (P < .01).
[c,d] Means different within main effect (P < .05).

Table 5. Effects of diet and feeding frequency on litter performance.

	Diet			Frequency		
Criteria	**Control**	**High Fiber**	**PSEM**	**1X**	**2X**	**PSEM**
No. of sows	122	117		116	123	
Litter size:						
Total born	11.7[a]	10.8[b]	0.252	11.2	11.2	0.252
Born alive	10.7[a]	9.8[b]	0.252	10.2	10.2	0.252
After cross-foster	10.9[a]	10.5[b]	0.088	10.6	10.9	0.088
Pigs weaned	9.7	9.9	0.071	9.8	9.8	0.071
Litter weight (lb):						
Birth	35.9	32.6		33.7	34.6	
After cross-foster	36.6	35.7		35.0	37.0	
Wean	137.8	138.2		136.2	139.8	
Avg. pig birth weight (lb)	3.3	3.3		3.3	3.5	
Avg. pig wean weight (lb)	14.1	14.1		13.9	14.1	

[a,b] Means different within main effect (P < .05).