RESEARCH REPORT

ANIMAL WELFARE

Title: Designer Diets Decrease Aggression and Increase Welfare - **NPB #12-196**

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Final Report: November, 19th, 2015

Industry Summary:

The current practice of pregnant sow housing uses individual housing in stalls. However, producers are under a great deal of pressure to return sows to group housing due to various reasons. There are several advantages and disadvantages of individual and group housing. The most striking and important advantage of individual housing is that it reduces physical aggression in group housed sows. Aggression has a big impact on sow welfare and productivity. This study proposed to modify diet by increasing fiber and fermentable carbohydrate in the diet to increase satiety in pregnant sows. These two methods increase satiety by two different methods. One mechanism increases gut fill, which reduces hunger to some extent, but does not eliminate it. The second method increases nutrient provisions in the blood further away in time from the meal, and triggers the feeling of satiety in the brain. This method too does not eliminate hunger entirely but is helpful in maintaining satiety for a longer duration. In this study, we combined these two separate methods of increasing satiety. We hypothesized that they would be additive in effect and more useful than each separately. Our experiment was to determine the effects of the different diets independently. Then our second experiment made combinations of the diets to determine if there was any additive effect.

In Experiment 1 sows were fed 1 of 5 diets: 1) control (corn/soybean standard diet), 2) resistant starch at 10.8% inclusion rate, 3) beet pulp at 27.2% inclusion rate, 4) soyhulls at 19.1% inclusion rate, or 5) soyhulls at a 14.05% inclusion rate but the amount of feed per sow was increased by .44 pounds over the 4.4 pounds fed in the other 4 treatments. Sows were maintained on these diets for 3 weeks after which they were mixed into groups of 5 and data were recorded to determine if sows fought less based on diet. Sows on soyhulls rested more during the 3 weeks on diets while sows on beet pulp stood more. Sham chewing increased for sows on all diets during the duration of the study but was lowest for sows on soyhulls. When the sows were mixed, sows on the control diet bit at each other the most while sows on the resistant starch diet bit at each other the least. Heart rate was lowest for sows on both the diets with soyhulls. Thus this study found that dietary inclusion of either resistant starch or soyhulls helped to improve welfare by reducing aggression and increasing satiety, without effecting production.

In Experiment 2 sows were fed 1 of 4 diets: control, ad libitum, 1.5 x the amount of resistant starch as fed in Experiment 1 (16.2% inclusion rate), and a 50:50 combination of resistant starch and soyhulls as fed in Experiment 1. The same procedures and measures were obtained as in Experiment 1. In this experiment, very few differences if any were detected for behavior, physiology or productivity, with sows on all treatments performing similarly. It is noted that in this experiment aggression of control sows was very low as compared to Experiment 2. This likely prevented treatment differences from being realized. It is not clear why aggression was low in this experiment.

In conclusion, resistant starch and soyhull diets similar to those as fed in Experiment 1 can be useful to decrease aggression and abnormal behaviors.

Keywords: aggression, dietary-fiber, resistant starch, satiety, sow, welfare

Scientific Abstract:

Experiment 1:

Aggression during mixing of pregnant sows impacts sow welfare and productivity. The aim of this study was to increase satiety and reduce aggression by including dietary fiber and fermentable carbohydrate. Sows were housed in individual stalls 7 to 14 d post-breeding and were fed (at 0700 h) with either a CONTROL (regular feed with no extra fiber), RSTARCH (10.8% resistant starch), BEETPULP (27.2 % sugar beet pulp), SOYHULLS (19.1% soybean hulls) or INCSOY (14.05% soybean hulls) for 21 d (5 sows/diet × 5 diets × 8 replications = 200 sows). The CONTROL diet was targeted to contain 185 g/d/sow NDF and other diets were targeted to contain 350 g/d/sow NDF. The INCSOY diet was fed at 2.2 kg/d/sow and other diets were fed at 2 kg/d/sow. On d 22, sows were mixed in groups of five (at 1200 h). Behaviors in stalls (on d 1, 7, 14 and 21) and after mixing (d 22 and 23), heart rate (on d 1, 7, 14 and 21), blood metabolites (on d 2, 8, 15, 22 and 25), and the effects of diets on production were collected and analyzed. Sows stood more ($P < 0.01$) and rested less ($P < 0.001$) over time irrespective of the diet. Sows on BEETPULP stood more ($P < 0.01$) and sows on SOYHULLS rested more ($P < 0.01$). Sham chewing increased over days irrespective of the diet. Chewing behavior (bar and feeder) increased with days on diet ($P < 0.001$) and was lowest in sows on SOYHULLS diet ($P = 0.045$). When mixed, biting frequency in the first hour was highest for sows on the CONTROL diet (236.5 ± 62.6) and lowest for sows on the RSTARCH diet (90.5 ± 30.5). Skin lesions increased ($P < 0.001$) 24 h after mixing sows irrespective of diet. Blood urea nitrogen (BUN) concentration was lowest in BEETPULP and SOYHULLS ($P < 0.001$). Serum glucose concentration was highest in RSTARCH and BEETPULP ($P = 0.04$), but there was no day effect ($P = 0.62$) or diet by day interaction ($P = 0.60$). The NEFA was greatest in RSTARCH, BEETPULP and SOYHULLS ($P < 0.001$). Lactate ($P < 0.001$) and BUN concentrations were greatest on d 2 but dropped and remained constant after d 8. Average heart rate was lowest for sows on SOYHULLS and INCSOY compared to other diets ($P = 0.03$). Number of piglets born and average weaning weight were not affected by diets ($P > 0.05$). Average birth weight was lowest in INCSOY diet ($P = 0.02$). This study demonstrates that RSTARCH and SOYHULLS can improve the welfare of sows by reducing aggression and increasing satiety in limit fed pregnant sows without affecting production.

Experiment 2:

The aim of this study was to increase satiety and reduce aggression by modifying the diets in Experiment 1 to include combinations of them or to increase their effectiveness. Sows were housed in individual stalls 7 to 14 d post-breeding and were fed (at 0700 h) with either a Control (regular feed with no extra fiber), Ad Libitum (as a control for satiated sows), resistant starch (16.2% inclusion rate), and resistant starch/soyhulls (8.1% resistant starch/8.05% soybean hulls). Unlike Experiment 1, in this study we found few to no differences in behavior, physiology, or productivity. It was observed that control sows in this experiment showed low levels of aggression as compared to sows in Experiment 1, likely causing any treatment differences to be non-existent. It

is concluded that the resistant starch diet and the soyhull diet as fed in Experiment 1 are the best candidates to decrease aggression and abnormal behavior through dietary means.

Introduction:

Gestation sow housing remains a contentious issue in the U.S. and legislation has now been passed in a number of states to move sows into group housing. However, without adequate management, group housing can severely impact the welfare of subordinate sows (Mendl et al., 1992). Although aggression at mixing is unavoidable, it is usually intense only over the first few hours as social hierarchies are being established (Pritchard, 1996). A number of different system design and management methods have been used to reduce aggression (see review by Marchant-Forde & Marchant-Forde, 2005) with variable results. As producers in the U.S. move towards group housing of sows during gestation, many are continuing to use stall housing for breeding. Sows are often placed in breeding stalls at weaning and groups are typically formed 30-35 days post-breeding by selecting sows with similar size and body condition. Previous work in our group has found that sows mixed into a group of three after being neighbors in breeding stalls for 12 or 40 days had higher post-mixing lesion scores than sows mixed into a group of three which were not neighbors in stalls (unpublished data), indicating heightened aggression between stalled neighbors. Aggression is a major challenge when group-housing pigs (Marchant-Forde & Marchant-Forde, 2005). Pigs will fight when mixed and when competing for access to feed, water, or preferential lying areas. The most immediate and obvious physical impact of aggression can be increased physical injuries (O'Connell et al., 2003) and resulting pain. Persistent aggression can decrease an individual pig's welfare in terms of increased injuries, pain, stress hormone concentrations, heart rates, compromised body condition and decreased sow productivity and can negatively impact immunity (Mendl et al., 1992; Marchant et al., 1995; Otten et al., 1999).

The reason that sows fight is to gain access to limited resources, such as a lying area, water, and food. This is important in swine production because sows are limit fed to 30% of what they would eat if given ad libitum access (Kirkden and Pajor, 2006). Thus, these sows are hungry. Increasing their level of satiety would have a significant impact on decreasing aggression and improving productivity. A true measure of satiety can only be obtained if one compares the behavior and motivation of a hungry sow with that of a satiated sow. This can be done by allowing sows full feed and comparing them to limit fed sows. Satiety can be assessed behaviorally because satiated animals are more restful and less active (de Leeuw et al., 2004; Zonderland et al., 2004; de Leeuw et al., 2008), less aggressive with one another (Danielsen and Vestergaard, 2001; Bolhuis et al., 2010; Stewart et al., 2010), and perform less stereotypic behavior (de Leeuw et al., 2008). Thus by comparing the behavior of satiated sows with those of sows on our various diets, we will be able to objectively determine if the diets are increasing satiety.

Although production diets are nutritionally balanced, their concentrated form may not provide enough gut distension (Brouns et al., 1994; Ramonet et al., 1999; Whittaker et al., 1998). Intentional undernutrition (feed restriction) can be further divided into *quantitative* and *qualitative* restriction. Quantitative restriction occurs when animals are restricted to some proportion of feed that is less than what they would consume if allowed to feed *ad-libitum.* A quantitative restriction situation is a common form of feeding practice with nearly all gestating sows provided a restricted diet. Quantitative restriction in gestating sows provides for a variety of production benefits including reduced fatness which improves fertility and lactation performance (Whittemore, 1998). The second category of intentional undernutrition is qualitative restriction where the nutritional composition of the diet is reduced, e.g., concentrated diets are often diluted with a non- or low-nutritive substance such as soybean hulls or beet pulp. However, if the diet is diluted so excessively that the animal cannot consume enough due to gut fill limits, hunger is still likely. Qualitative restriction is frequently offered as an alternative to quantitative restriction that can improve welfare while maintaining production performance. In swine, the benefits of diluted diets are seen with a greater display of foraging behaviors (Bergeron et al., 2000), increased time spent eating (Robert et al., 1993), and a reduction in stereotypic behaviors (Bergeron et al., 2000; Robert et al., 1993; Robert et al., 1997). Despite the successes of diet dilution at reducing signs associated with poor welfare, abnormal behaviors are still performed albeit reduced leading some to question their actual effectiveness (Fraser, 1975; Jensen, 1988; Meunier-Salaun et al., 2001).

Greater dietary fiber has been proposed to enhance the satiating properties of a meal by increasing feeding duration and decreasing foraging behavior (Danielsen and Vestergaard, 2001). Bergeron et al. (2000) used motivation testing in their effort to evaluate the effect of either: various levels of dietary fiber, a control diet with little dietary fiber fed at a restricted amount, or the same control diet fed *ad-libitum*. They found that the high fiber diet did decrease stereotypic behavior and activity, although not as well as the ad libitum diet. Increasing dietary fiber has been shown to reduce motivation for feed only minimally in Bergeron et al. (2000). Lastly, it is likely that the amount as well as source of fiber play a role in the resulting hunger motivation and will require further investigation (Ramonet et al., 2000; Robert et al., 1997).

In addition to fiber to increase bulk, others have tried altering carbohydrates in the diet to increase satiety. Adding the fermentable carbohydrates has been shown to decrease sow activity (Bolhuis et al. 2008; Schrama and Bakker, 2008) and aggression (Bolhuis et al., 2010), suggesting that these diets increased satiety. In a review which evaluates the usefulness of fiber and fermentable carbohydrates, de Leeuw et al. (2008) note that high fiber diets appear to cause satiety in the short term, partly through gut distension. Fermentable fiber diets are slower to release nutrients into the blood and thus increase satiety less immediately after a meal but for a longer duration. Thus it was the goal of this research project to combine those dietary amendments that work through complimentary mechanisms to more effectively cause satiation in swine.

Objectives:

The objectives of these experiments were: 1) to design diets that would increase satiety of sows when compared to conventional diets; and 2) to determine if combinations of dietary modifications were more effective than either modification on its own at increasing satiety.

Materials and Methods:

Experiment 1:

A total of 200, York × Landrace sows (25 sows/ replication × 8 replications; parity 1 to 6) were used. Four treatment diets were compared to control diet in pregnant sows. Sows were fed a diet of either: Resistant Starch (R-Starch, 10.8%, 4.4 lb/day), Beet Pulp (27.2%, 4.4 lb/day), Soyhull (19.1%, 4.4 lb/day), Increased Soyhull (Inc-Soyhulls, 19.1%, 4.84 lb/day), or a Control diet (4.4 lb/day). Forty sows were used for each treatment. Sows were bred when they were in heat. On day 7 to day 14 after breeding, sows were moved into the experimental building and housed individually in 0.61 × 2.13 m gestation stalls. The sows were placed in the gestation stalls such that groups formed later from these sows would not be from neighboring stalls. Sows were maintained on these diets in the gestation stalls for 21 days and were moved into group pens when they were 28-35 days pregnant. When grouped, sows were housed in 2.13 × 3.05 m pens and fed in stalls (0.61 × 2.13 m) connected to the pen area. The behaviors of the sows were recorded weekly (24 hours every week, Table 1) in the stalls and for 3 days at grouping. Heart rates were collected in 2 focal sows in each treatment when they were individually housed in stalls on days 1, 7, 14 and 21 after they were moved into the stalls. On days 2, 8, 15 and 22, blood samples were collected from the same focal sows. On day 22, sows were moved into groups corresponding to their diets. Blood samples were collected again on day 3 of mixing. The physiologic response to the diets (non-esterified fatty acids, blood urea nitrogen, glucose and lactate) were assessed by using blood serum. Serum samples have been collected and stored at -80 ^{0}C for lab analysis. Data on body condition score, back fat and weights of the sows were collected on days 1 and 21 of individual housing. Numbers of lesions on body parts of the sows were assessed before grouping and daily during 3 days of mixing as an additional measure of aggression. To quantify lesions, the number of lesions were counted for each of 6 body areas of the sow (Figure 1). Sows were returned to the normal Purdue farm gestation diet after day 3 of group observation.

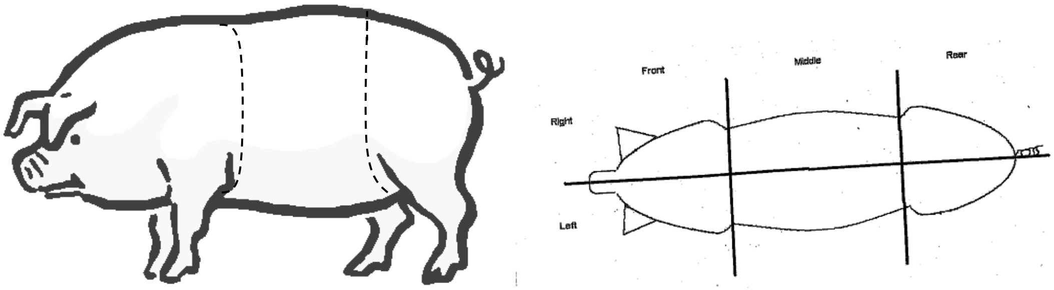

Figure 1. Parts of body of sows in which lesions are counted.

<u>*Experiment 2.*</u>

Experiment 2 followed the exact same procedures as Experiment 1 except that sows were fed a diet of either: control, ad libitum, combination (50:50) of resistant starch and soyhulls as used in Experiment 1, or resistant starch at 1.5 x the levels as fed in Experiment 1. In total, 160 sows were assigned to one of 4 treatments.

Results:

<u>*Experiment 1:*</u>

Behavior

Sows spent more time standing on d 14 and 21 compared to d 1 and 7. When in stalls, the sows fed the beet pulp diet stood more than all other diets with the sows fed other four diets spending equal amounts of time standing. The percentage of sows resting was highest when fed soyhulls and lowest in on the beet pulp diet.

Sham-chewing was not affected by diet. When sows were mixed on d 21 of treatment, biting frequency in the first hour of mixing was highest in the control and soyhull treatment and lowest for sows on the resistant starch diet. Aggression was numerically lowest in the first hour for sows fed resistant starch diet (Figure 2) but due to the large degree of variation did not prove to be significant. However, fighting frequency in the first hour was lower for sows on the resistant starch diet and the increased soyhull diet when compared to controls (12.7, 11.4, and 18.7 respectively). Biting frequency, fighting duration, head-knock frequency, bite frequency and head-knock frequency in hours 2, 3 and 4 did not differ among diets. On d 2 of mixing, aggressive interactions lasted only for less than 1 min in first 4 h after feeding and did not differ among treatments. Because duration of aggressive interaction was so low, detailed analysis on other measurements of aggression was not done on d 2.

Skin Lesions

Diet did not affect the total number of skin lesions counted at 24 h, 48 h or 72 h post-mixing. However, as expected, total number of skin lesions were higher in each diet after 24 h of mixing (d 23) compared to baseline (d 21). The number of skin lesions did not differ with respect to the different body areas (front, mid and rear) on any of the days of mixing.

Blood metabolites

The blood urea nitrogen concentration was affected by days on being highest on d 2 compared to d 8, 15, 22 and 25, but there was not a diet by day interaction. The glucose concentration was affected by diet (Table 1). Non-esterified fatty acids were also affected by diet (Table 1). Lactate in the blood serum was not affected by diet. Lactate concentration was highest on day 2 (30.2 ± 0.31 mg/dl) and lowered and remained constant with increasing days (28.3 ± 0.35, 28.0 ± 0.32, 28.1 ± 0.34 and 28.3 ± 0.37 mg/dl on d 8, 15, 22 and 25 respectively).

Heart Rate Variability

The RR-min was lowest on d 21 (690 ± 18 ms) compared to RR-min on d 1, 7 and 14 (764 ± 16, 779 ± 18 and 777 ± 18 ms, respectively). The HR-max was also highest on d 21 (88.2 ± 2.0) compared to HR-max on d 1, 7 and 14 (79.4 ± 1.8, 77.8 ± 2.0 and 77.9 ± 2.0 bpm, respectively). The sows fed INCSOY and SOYHULLS diets had lowest HR-average compared to other diets. Diets, days on diets or interaction of days and diets did not affect RR-max, HR-min, SD, Variance and RMSSD.

Production

Diets did not affect body weight, back fat, and body condition score. Change in body weight, BF and BCS were calculated as difference of d 21 and d 0 of respective measures. Change in body weight, BF and BCS were also not affected by the diets. Diets did not affect the number of piglets born or average weaning weight.

Experiment 2.

Behavior

Analyzing the behavioral data after mixing we found that aggressive interactions (Figure 3), bites, and head knocks were not different between treatments. It is also noted that this experiment aggression was much lower for control sows compared to that found in Experiment 1 which likely prevented treatment differences. The reason for this low rate of aggression in this experiment is unclear.

Skin Lesions

Overall skin lesions were not different across treatments which is in agreement with the behavioral data which showed aggression to be the same for all sows. However, we did note that lesions on the middle, right side of sows in the resistant starch and resistant starch/soyhull diets were greater than controls. It is likely that this is a statistical artifact.

Blood Metabolites

Non-esterified fatty acids were greater in sows fed the resistant starch and the resistant starch/soyhull diet when compared to controls. No treatment differences in glucose or lactate was found. And blood urea nitrogen was lower for most days for sows on the resistant starch and the resistant starch/soyhull diet when compared to controls.

Production

As expected, sows on ad libitum feed had greater back fat, body condition scores, and body weight at the end of the study. No differences in production were found.

Discussion:

In Experiment 1, resistant starch did reduce aggression in the first hour of mixing but might not be different from control diet or other sources of fiber in terms of affecting overall behavior in their stall, peripheral blood metabolites, aggression at mixing, skin lesions after mixing, heart rate variability and production. The sows on beet pulp diet stood more compared to control, resistant starch, soy hulls and increased intake. Soy hulls could be added to the diet to reduce heart rate. In conclusion, including resistant starch and soy hulls in a proper proportion in the diet fed three weeks prior to mixing might be effective in overall reduction of aggression, restlessness and heart rate and improve sow welfare during mixing.

In Experiment 2, we found very little differences across treatments to indicate any behavior, physiology, or welfare benefits. The differences noted were those that would be expected from feeding different nutrients and amounts. There was no additive effect of feeding more resistant starch or combining resistant starch with soyhulls.

Thus we conclude that the resistant starch and soyhull diet used in Experiment 1 may offer the most benefit in terms of reducing aggression and enhancing sow welfare.

Table 1. Effect of diet on blood metabolites concentrations by treatment on average.

	Diets					*P*		
Metabolites	CONTROL[1]	RSTARCH[2]	BEETPULP[3]	SOYHULLS[4]	INCSOY[5]	Diet	Day	Diet × day
BUN (mg/dl)	10.7 ± 0.4^{a}	10.0 ± 0.5^{a}	8.2 ± 0.4^{b}	8.8 ± 0.4^{b}	10.1 ± 0.4^{a}	<0.001	<0.001	0.71
Glucose (mg/dl)	71.3 ± 1.3^{a}	75.2 ± 1.4^{bc}	76.4 ± 1.3^{c}	72.8 ± 1.2^{ab}	72.4 ± 1.1^{ab}	0.04	0.62	0.60
NEFA (mmol/l)	0.5 ± 0.05^{a}	0.7 ± 0.06^{b}	0.7 ± 0.05^{b}	0.8 ± 0.04^{c}	0.6 ± 0.04^{a}	<0.001	0.36	0.60
Lactate (mg/dl)	28.7 ± 0.3	28.0 ± 0.4	28.8 ± 0.3	28.5 ± 0.3	28.9 ± 0.3	0.49	<0.001	0.71

[a, b] Means within a row with different superscripts differ ($P < 0.05$).
[1]CONTROL: regular feed with no extra fiber, 2.0 kg/d, 185 g/d NDF
[2]RESISTANT STARCH: 10.8% resistant starch, 2.0 kg/d, 350 g/d NDF
[3]BEETPULP: 27.2 % sugar beet pulp, 2.0 kg/d, 350 g/d NDF
[4]SOYHULLS: 19.1% soybean hulls, 2.0 kg/d, 350 g/d NDF
[5]INCSOY: 14.05% soybean hulls, 2.2 kg/d, 350 g/d NDF

Figure 2. Experiment 1. Aggression during the 1st, 2nd, 3rd, and 4th hours after mixing; for sows on the control diet, resistant starch diet, beet pulp diet, soyhull diet, and soyhull diet with .4 lbs extra feed provided.

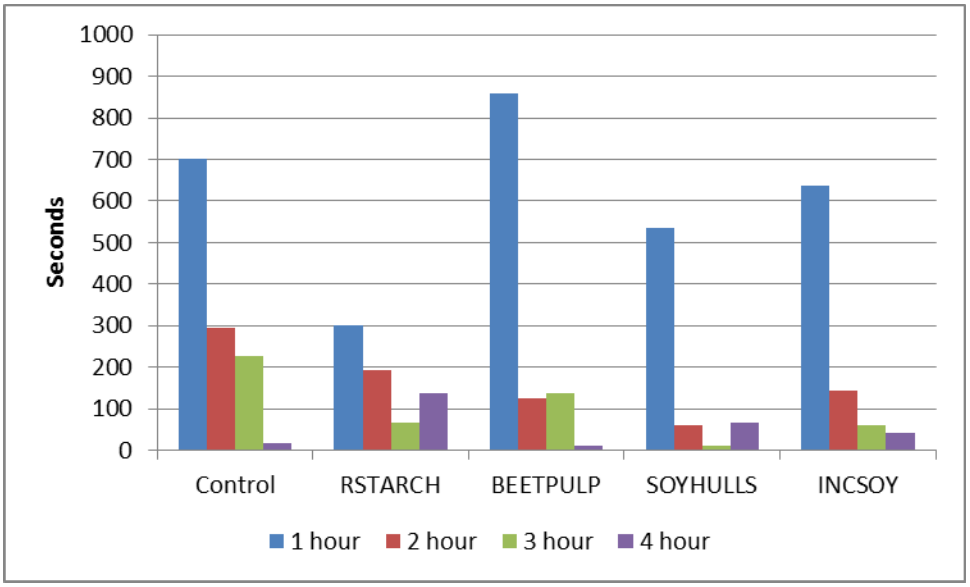

Figure 3. Experiment 2. Aggression during the 1st, 2nd, 3rd, and 4th hours after mixing; for sows on the control diet, ad libitum diet, 1.5 x resistant starch as used in Exp. 1, and diet with both resistant starch and soyhulls.