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Controlling aggression at grouping of gestating sows

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Abstract

A major concern about group-housed gestating sows is aggression at grouping. The initial aggression induced by grouping can elevate stress hormone cortisol concentration, cause injury, and reduce farrowing rate in sows. There is evidence that aggression is associated with excitement, and suppressing excitement reduces aggression. Tryptophan (Trp), a precursor of serotonin, suppresses excitement and aggression in humans and several species of animals, including growing and finishing pigs. However, effects of Trp supplementation on controlling aggression among gestating sows has not been documented. The objective of this study was to determine effects of Trp supplementation on controlling aggression, the associated stress and reproductive performance in group-housed gestating sows.

The study was conducted on a 150-sow farrow-to-finish commercial farm. All gestating sows were group-housed with electronic sow feeders (ESF) on concrete partially slatted floors. Sows were grouped in a gestation pen after weaning. Each gestation pen accommodated 25 ± 5 sows, giving approximately 24 ft^2 floor space allowance to each sow. A total of 192 multiparous sows from 8 breeding groups were used in the study, with 4 groups (pens) receiving the control diets, and 4 groups receiving the treatment diets. Control sows received regular diets (NRC requirements) throughout gestation (0.15% Trp) and lactation (0.2% Trp). Trp sows received two times the required dietary Trp, 0.3% Trp in the gestation diet and 0.4% Trp in the lactation diet three days before and after grouping. From the 4^{th} day after grouping, Trp sows were switched to and remained on the control diet for the rest of the gestation period. Six focal sows (2 sows from each of parity 1, 2, and 3 or greater) in each pen were designated and videotaped after grouping for 72 hours to determine the number and type of aggressive interactions among sows. Before and 48 hours after grouping, saliva samples were taken from the focal sows, and scratches resulting from aggression were assessed on all sows. Data were analyzed by using the Frequency procedure (Chi-square) and the Glimmix procedure of SAS to test the treatment effect, with pen serving as the experimental unit. Aggression among sows was intense during the first 6 hours (192 sec/hour per sow), and decreased dramatically between 6 to 72 hours (72 to 41 sec/hour per sow, SE= 23.6; $P < 0.001$) after grouping. The initial aggression caused scratches and elevated cortisol concentrations in sows. Mature sows fought for longer periods (116 vs. 52 sec/hour per sow), but had fewer scratches caused by aggression (total injury score = 4.6 vs. 6.8, SE = 1.13; $P < 0.05$) than parity 1 sows. Supplementation of dietary Trp reduced the total duration of head-to-head knocking (4.9 vs. 8.6 sec/hour per sow, SE = 0.96; $P < 0.05$), but did not affect other aggressive behaviors. There was no difference in injury scores or in saliva cortisol concentrations between the treatments. Trp sows had more total born piglets (12.6 vs. 10.5 piglets/litter, SE = 0.54; $P < 0.01$), and more piglets born alive (10.9 vs. 9.7 piglets/litter, SE = 0.44; $P < 0.05$) at farrowing, but had lower breeding rate (82 vs. 94%, Chi-sq=6.3; P < 0.01) than Control sows. These results indicate that the therapeutic use of Trp to suppress aggression in group-housed gestating sows is more complicated than in other species or in young pigs. Further research is needed to investigate the optimal amount and period of Trp supplementation on aggression and performance of gestating sows in group housing systems.

Introduction

Group housing of gestating sows has been perceived as a model, welfare-friendly system because it allows sows freedom of movement, choice of micro-environment, and performance of natural behaviors. Indeed, sows from group housing have less stereotypies and are easier to handle (Mendl et al., 1993; Jensen et al., 1995) compared with sows in gestation stalls. The long-term benefit of group housing appears more significant. After spending several gestations in group housing, mature sows tend to produce larger litters (Mendl et al., 1993; Gonyou, 2004), and have stronger legs (Marchant and Broom, 1996) than sows housed in gestation stalls. During the late stage of gestation, group-housed sows had lower cortisol levels than stalled sows (Hemsworth et al., 2006). However, a major concern of group housing is aggression at grouping. Although aggression at grouping is relatively short-lived, its deleterious impact on welfare and productive performance cannot be overlooked. The elevated aggression causes injuries (Hodgkiss et al., 1998) and increases cortisol levels in sows (Hemsworth et al., 2006). When grouped during the implantation period, aggression reduces conception rate, especially in younger sows (Olsson and Svendsen, 1997). Failure of conception can result in sows being culled prematurely. The high culling rate in young sows, as is often observed in group housing, can be attributed to aggression and the associated stress at grouping. To maintain young sows through the first three parities in group housing, controlling aggression at regrouping is an essential step.

Aggression among sows at grouping is intense during the first few hours and drops dramatically after 24 hr (Mendl et al., 1993; Moor et al., 1993; Spoolder et al., 1997). One week after grouping, a stable social group is formed (Arey, 1999). Social rank in a group of sows affects aggression at grouping. Older sows are involved in most fights. But younger sows lose most fights, and suffer more injuries and higher cortisol levels than older sows (Edwards et al., 1994; Hemsworth et al., 2006). The initial aggression results in subordinate sows becoming fearful of further conflicts while attempting to obtain feed which leads to inadequate feed intake and potentially, reproductive failure.

Several methods to control aggression in pigs have been investigated. There is evidence that aggression is associated with excitement, and suppressing excitement at regrouping reduces aggression (Luescher et al., 1990). Tryptophan (Trp), a precursor of serotonin, reduces aggression in humans and animals. Tryptophan is one of the ten essential amino acids that must be obtained from dietary protein for normal body function. Although dietary tryptophan is predominately metabolized by the liver, excess tryptophan leaves the liver to be taken up by the brain where it is converted to the neurotransmitter, 5-hydroxytryptamine (5-HT), also known as serotonin. Serotonin has a sedative effect by suppressing aggression, excitement, anxiety and pain. Oral administration of synthetic tryptophan suppresses aggression and excitement in several species. In horses, Trp has been used in calmative agents to treat excitable horses (Grimmett and Sillence, 2005). In poultry, supplementation of twice the required Trp in the diet effectively suppresses aggression in broiler breeder males (Shea et al., 1990, 1991). In companion animals, supplementation of dietary Trp reduces dominance aggression and territorial aggression in adult dogs (DeNapoli et al., 2000). In fish, supplementation of Trp in the diet for seven days significantly reduced aggression in juvenile trout and cod (Winberg et al., 2001; Hoglund et al., 2005). In swine, supplementation of twice the required Trp to grow-finish pigs for two days significantly reduced aggression at regrouping (Li et al., 2006). However, effects of Trp supplementation on controlling aggression among gestating sows has not been documented.

Objectives

The objective of the study was to determine effects of short-term supplementation of dietary Trp on aggression at grouping, the associated stress and reproductive performance in gestating sows.

Procedures

Animals and Facilities

The study was conducted on a 150-sow farrow-to-finish commercial farm in Montgomery, MN between October, 2006 and June, 2007. All sows were group-housed with electronic sow feeders (ESF) on partially slatted concrete floors. Each gestation pen, measuring 25.5 x 24.5 ft, accommodated about 25 (±5) sows. The floor space allowance was approximately 24 ft^2 per sow excluding the space occupied by the feeder station. The group-housing system was managed by a static program. Four pens were used for gestating sows and one pen was the mixing/breeding pen. Every 4 weeks a group of 25±5 sows was moved to the breeding pen after weaning. Sows were bred by artificial insemination and remained in the breeding pen until pregnancy check at 4 weeks after breeding. Once confirmed pregnant, the sows were moved to a gestation pen and remained there for the rest of the gestation period. All sows received a corn-soybean meal based diet and had 24-hr access to an electronic feeding station. Thermal environments in the gestation barn were controlled by heaters, cooling fans, and natural ventilation. The light period was about 10 hours starting at 7:00 am.

The study was conducted in four blocks. Each block included a group of sows receiving the control diets and a group of sows receiving the treatment diets. In total, 8 breeding groups of sows (parity 1-13) were used, with 4 groups (pens) receiving the control diets, and 4 groups receiving the treatment diets. All sows had been housed in pens with electronic sow feeders during their previous gestation. Gilts were separately housed from the sows during gestation, and consequently not included in the study. In total, 192 sows were used for data collection, with 94 sows in the control group and 98 sows in the treatment group.

Tryptophan supplementation

Sows in the control group received standard diets formulated according to NRC (1998) nutritional requirements throughout gestation (0.15% Trp) and lactation (0.2% Trp). Sows in the treatment group received two times the required Trp in the diets (0.3% Trp in the gestation diet, and 0.4% Trp in the lactation diet) three days before and after grouping. From the 4th day after grouping, treatment sows were switched to and remained on the control diet for the rest of the gestation period.

Data Collection:
To investigate effects of the dietary treatment on aggression, the associated stress and reproductive performance, the following data were collected:

Aggression at grouping

Six focal sows were designated within each pen and identified with simple paint markings. These focal sows included two sows from each of parity 1, 2, and 3 or greater. Immediately after grouping, behavior of the focal sows was recorded for 72 hours using digital cameras and a computer with a digital video recording device. The video recording was viewed continuously to analyze aggression involving the focal sows during each period of 0 to 6 hours, 6 to 24 hours, 24 to 48 hours, and 48 to 72 hours after grouping. Intensity of aggression was assessed by parallel pressing, head-to-body knocking, and head-to-head knocking according to the methods of Jensen (1980). Parallel pressing was defined as the sows that stand side by side and push hard with the shoulders against each other, generally performing with frequent bites. Head-to-body knocking was defined as a sow delivering knocks with the snout against the body of the receiver, generally performed with bites as accessory features. Head-to-head knocking was defined as a sow delivering knocks with the snout against the head of the receiver, generally performed with bites as accessory features. The intensity of aggression is the highest in parallel pressing, the lowest in head-to-head knocking, and intermediate in head-to-body knocking. Total duration and frequency of pressing and knocking were calculated for each focal sow within a pen.

Injury scores

All sows in each pen were assessed for scratches before and 48 hours after grouping. Injuries caused by aggression were estimated by the difference between the two assessments. Scratches were assessed using the methodology of Hodgkiss et al. (1998). The assessment combined scores of 0 to 3 from twelve surface regions of the body: two ears, snout, two shoulders, two flanks, two hindquarters, top of the back, tail, and vulva. The scoring system was: 0 = No injury (skin unmarked: no evidence of injury from aggressive behavior), 1 = Slight injury (< 5 superficial wounds), 2 = Obvious injury (5-10 superficial wounds and/or <=3 deep wounds), 3 = Severe injury (> 10 superficial wounds, and/or > 3 deep wounds). For the purpose of assessing aggression-induced injuries, an injury score for the head and shoulders (by adding injury scores on the ears, the snout, and the shoulders), an injury score for the remaining parts of the body (by adding injury scores on the flanks, the hindquarters, the back, the tail and the vulva), and a total injury score for each animal was calculated. The injury score for the head and shoulders was more associated with injuries caused by aggression than the injury score for the remaining parts of the body (Turner et al., 2006).

Salivary cortisol

Saliva samples were obtained from the focal sows at 13:00 h on the same days that injuries were assessed. Saliva was collected using absorbent cotton swabs with minimal disturbance to the sows. To avoid cortisol level elevated by handling stress, each saliva sample was collected within 2 minutes of approaching the sow. Saliva was removed by centrifugation, and frozen for subsequent analysis. Cortisol concentration was determined by radioimmunoassay according to the methods of Cook et al. (1996).

Performance

Feed intake and feeding behavior. The proportion of animals entering the ESF station each day and the proportion of total feed allotment that was consumed by each sow were collected from sow feed records from the day of mixing through day 7 after grouping.

Breeding rate, farrowing rate, and litter size. Standard production data, including breeding rate (number of sows bred as a percentage of number of sows weaned), farrowing rate (number of sows farrowed as a percentage of number of sows bred), total litter size, live litter size, and still born piglets were collected at the farrowing subsequent to treatment at mixing.

Dietary Trp

Samples were collected from all diets, including both control and treatment diets. Two samples of every batch of the diets were retained for subsequent analysis. Trp concentration of the diets was determined for each replicate.

Data analysis:

The Frequency procedure with Chi-square test of the SAS program (SAS Inst. Inc Cary NC; 2005) was used to examine effects of the dietary treatment on the proportion of sows bred and farrowed. The Glimmix procedure of SAS was used to analyze all other variables. The treatment was the fixed effect, and block was the random effect with pen as the experimental unit. Effects of parity were tested as a sub-plot within pen.

Results

During the study period, room temperatures were controlled close to the thermoneutral zone for gestating sows. The maximal and minimal daily room temperatures in the gestation barn were 78 ^{o}F and 48 ^{o}F, respectively. The average group size at mixing was similar between Control (23.5 ± 1.12 sows/pen) and Trp (24.5 ± 3.28 sows/pen) groups. The distribution of sow parity within each pen was similar between Control and Trp treatments. Within each pen of the Control group, 26% of sows were parity 1, 27% of sows were parity 2, and 47% of sows were mature sows (parity 3 or greater). In the Trp group, 28% of sows were parity 1, 23% of sows were parity 2, and 49% of sows were mature sows within each pen. The analyzed Trp concentrations were 0.15% Trp (gestation) and 0.20% Trp (lactation) in the control diets, and 0.35% Trp (gestation) and 0.48% (lactation) in the treatment diets, respectively, which were either equal to or greater than the Trp concentrations in the formulations. Feed intake and feeding behavior data were excluded from the analysis because of missing data caused by modification of the ESF computer system.

Aggression at grouping

Effects of the dietary treatment on aggressive interactions at grouping are presented in Table 1. Trp supplementation decreased the total duration of head-to-head knocking (4.9 vs. 8.6 sec/hour per sow, SE = 0.96; $P < 0.05$). The dietary treatment did not affect head-to-body knocking and parallel pressing, which are more intense aggressive interactions among sows.

Effects of sow parity on aggressive interactions at grouping were observed (Table 2). The total duration of parallel pressing was increased with parity. Parity 1 sows had shorter duration of parallel pressing than mature sows (52 vs. 116 sec/hour per sow, SE = 20.1; $P < 0.05$). No interactions between the dietary treatment and parity were observed.

The aggressive interactions decreased with the time period after grouping (Table 3). The frequency and the total duration of head-to-head knocking tended to decrease ($P = 0.06$) 6 hours after grouping. The frequency and the total duration of head-to-body knocking and parallel pressing decreased dramatically 6 hours after grouping ($P < 0.001$). No interactions between the dietary treatment and the time period were observed.

Injury scores associated with aggression at grouping

Before grouping, total injury score for Trp sows was higher than Control sows (Table 4, $P < 0.05$). There were no differences in injury scores after mixing between Trp and Control sows. The dietary treatment did not affect injury scores caused by aggression.

The injury score for the head and shoulders and the total injury score for a sow decreased with parity after grouping, with parity 1 sows having higher scores than parity 3+ sows ($P < 0.05$; Table 5). Similarly, injury scores for the head and shoulders and the total injury score caused by aggression were higher in the younger sows than in the mature sows ($P < 0.05$). No interactions between Trp supplementation and parity on injury scores were observed.

Cortisol concentration

Cortisol concentrations in saliva were similar between the two treatment groups before grouping (Table 6). After grouping, cortisol concentrations increased dramatically in both the treatment and the control group ($P < 0.001$). The dietary treatment did not affect cortisol concentrations in sows after grouping. There was no difference in cortisol concentrations among sows of different parities (Table 7).

Reproduction performance

Among the 192 sows weaned, 168 were bred (Table 8). Among the 24 sows not bred, 18 sows received supplemental Trp and 6 sows were assigned to Control. The breeding rate was lower in Trp group compared with that in Control group (81.6 vs. 93.6%, Chi-sq = 6.30; $P < 0.01$). There was no difference in farrowing rate between the treatment and the control group. Sows in Trp group had more total born piglets (12.6 vs. 10.5, SE = 0.54; $P < 0.01$) and piglets born alive (10.9 vs. 9.7, SE = 0.44; $P < 0.05$) per litter than sows in Control group. The larger litter size in the treatment group was associated with more stillborn piglets per litter (1.5 vs. 0.7, SE = 0.20; $P < 0.01$) compared with sows in the control group.

Discussion

In this study, aggressive interactions among sows at grouping were assessed by the aggressive intensity. From knocking to pressing, the aggressive intensity increases, with the head-to-head knocking being the least intense aggression, and parallel pressing the most intense aggression (Jensen, 1980). Although Trp supplementation decreased the total duration of head-to-head knocking, it did not affect parallel pressing which is the most aggressive interactions and causes most damage in swine (Turner, 2006). Consequently, no treatment effects on injuries scores or salivary cortisol concentrations were observed. These results suggest that excess Trp supplementation in diets for a short period has very limited effect on controlling aggression among sows at grouping. This is contradictory to the results from previous research on other species (Shea et al., 1990, 1991; DeNapoli et al., 2000; Grimmett and Sillence, 2005) and on young pigs (Li et al., 2006). Several factors may be attributed to the discrepancy between this study and the other previous studies. A possible factor contributing to the discrepancy might be the amount of Trp supplementation in the current study was inadequate to sedate gestating sows at grouping. The sedative effect of Trp relies on Trp concentration in the brain blood which depends on the surplus amount of Trp in the body. Since the required dietary Trp is metabolized by the liver, only surplus Trp can leave the liver and pass through the blood-brain barrier where it is converted to serotonin. Inadequate amount of supplementation may result in no surplus Trp in the blood. The Trp supplementation level in this study was designed based on previous studies on growing and finishing pigs (Li et al., 2006), and poultry (Shea et al., 1990). In those studies, including twice the required Trp in the diet effectively suppressed aggression among growing-finishing pigs and in young male broilers. However, in gestating sows, limit-feeding may change the metabolic profile of Trp. Possibly, the excess dietary Trp was metabolized in the liver and used as an energy source instead of being taken by the brain. Another reason for the discrepancy could be the high motivation for fighting among gestating sows due to feed restriction. Animals fight for resources. When resources are limited, motivation for aggression among animals elevates. Compared with ad libitum feeding, limit-feeding increases aggressive interactions among breeding animals (Shea et al., 1990), including gestating sows (Spoolder et al., 1997). Nevertheless, it seems that effects of Trp supplementation on controlling aggression may vary depending on satiation and motivation for aggression. The optimal amount and period of Trp supplementation for effectively controlling aggression in limit-fed gestating sows need further investigation.

In agreement with previous studies (Hemsworth et al., 2006; Strawford et al., 2008), results from this study showed that aggression increased with parity. Mature sows fought for longer periods than younger sows. In fact, the total duration of parallel pressing in mature sows was twice as long as in parity 1 sows. However, the increased fighting duration was not associated with injuries caused by aggression in mature sows. In contrast, injury scores caused by aggression decreased with parity. Parity 1 sows had more injuries from aggression than in mature sows. In agreement with results of other research (Edwards et al., 1994; Hemsworth et al., 2006; Strawford et al., 2008), our results further indicate that younger sows are victims of aggression, and their welfare is more compromised than mature sows at grouping. Sorting sows by parity and separating younger sows from mature sows may alleviate aggression-induced injuries in younger sows, which would improve welfare of younger sows in group housing systems.

Aggression among sows decreased dramatically after 6 hours of group housing in the present study, similar to that observed in other studies (Mendl et al., 1993; Moor et al., 1993; Spoolder et al., 1997). Six hours after grouping, there was no further decrease in aggression among sows. However, it is worthwhile to note that aggressive interactions among sows were still observed on the third day after grouping.

After grouping, cortisol concentrations in saliva increased dramatically indicating an elevated stress response caused by grouping. Trp supplementation did not affect cortisol concentrations after grouping. This further indicates the limited effect of Trp supplementation on controlling aggression and associated stress in gestating sows in the current study.

In contrast to previous studies (Hemsworth et al., 2006; Strawford et al. 2008), we did not find effects of parity on cortisol concentrations in sows at grouping. Hemsworth et al. (2006) reported that corisol concentrations in newly-mixed sows decreased with parity. Strawford et al. (2008) noted that parity 1 and mature sows had higher cortisol concentrations compared with parity 2 and 3 sows, which was coincident with the higher injury scores in parity 1 sows, and longer fighting durations in mature sows. In our study, neither the high injury scores in parity 1 sows nor the longer fighting duration in mature sows were associated with elevated cortisol concentrations.

In the current study, sows supplemented with Trp had a lower breeding rate. It is not clear whether the low breeding rate was associated with Trp supplementation because many factors, such as sow performance during the previous lactation, injuries including lameness, and management decisions to meet specific breeding goals, can affect the breeding rate. Somehow, it happened that sows in the treatment group had higher injury scores than sows in the control group before grouping. The higher injury score may result in high culling rate before breeding, which consequently reduced the breeding rate. In contrast to reduced breeding rate, Trp supplementation increased litter size at farrowing. Sows in the Trp group had more total born, born alive, and stillborn piglets per litter compared with sows in the control group. This was not expected, and no similar results have been reported. In a study aiming at improving reproductive performance of gilts, Sein and Chepeleve (1990) found that supplementation of lysine, methionine, threonine and Trp to gilts enlarged the uterus and ovaries. In their study, gilts receiving supplementation of the amino acids increased the weight, length, and volume of the uterine horns compared with gilts not receiving the supplementation. This may consequently increase litter size at birth. However, whether supplementation of Trp alone would have the same effect on uterine size and weight is not clear.

Trp supplementation did not affect farrowing rate. The overall farrowing rate was lower on the farm compared with the average farrowing rate on confinement commercial farms (PigChamp, 2009). With the limited number of sows used in the current study, we cannot make a confident conclusion on effects of Trp supplementation on reproductive performance of sows. Instead, the results of this study indicate that the therapeutic use of Trp to suppress aggression in group-housed gestating sows seems more complicated than in other species or in young pigs.

Summary

This study demonstrated that aggression among sows was intense during the first 6 hours, and decreased dramatically between 6 to 72 hours after grouping. The initial aggression caused scratches and elevated stress hormone cortisol concentrations in sows. Mature sows fought for longer periods, but had fewer scratches caused by aggression than parity 1 sows. The greater aggression-induced injury in parity 1 sows implicates welfare concerns for these young sows in group-housing systems. Supplementation of dietary Trp at twice the recommended inclusion rate for three days before and after mixing did not effectively reduce aggression and the associated stress in sows at grouping. Trp supplementation increased litter size at farrowing, but decreased breeding rate in sows. These results indicate that the therapeutic use of Trp to suppress aggression in group-housed gestating sows is more complicated than in other species or in young pigs.

Acknowledgement

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Table 1. Effects of supplementation of dietary Trp on aggression of dry sows during the first 72 hours after grouping

	Dietary Trp Treatment			*P*-value
	Control	Trp	SE	
# of pens	4	4		
# of focal sows/pen	6	6		
Head-to-head knocking				
Frequency, #/h/sow	1.9	1.2	0.27	0.13
Total duration, sec/h/sow	8.6	4.9	0.96	0.04
Head-to-body knocking				
Frequency, #/h/sow	1.0	1.1	0.22	0.77
Total duration, sec/h/sow	4.6	5.7	1.21	0.56
Parallel pressing				
Frequency, #/h/sow	2.0	1.7	0.22	0.30
Total duration, sec/h/sow	73.0	93.8	12.26	0.29

[a,b] Means without a common superscript within a row differ ($P < 0.05$).

LS means of the Glimmix Procedure of the SAS. Pen was the experimental unit.

Data presented in the table are the aggressive interactions involving focal sows.

Table 2. Effects of parity on aggression among dry sows during the first 72 hours after grouping

	Parity Of Sows				*P*-value
	Parity 1	Parity 2	Parity 3+	SE	
# of pens	8	8	8		
# of focal sows/pen	2	2	2		
Head-to-head knocking					
Frequency, #/h/sow	1.2	1.5	1.9	0.26	0.17
Total duration, sec/h/sow	5.0	6.0	8.5	1.13	0.17
Head-to-body knocking					
Frequency, #/h/sow	0.8	1.3	1.0	0.22	0.34
Total duration, sec/h/sow	3.5[c]	7.6[d]	4.6[cd]	1.18	0.06
Parallel pressing					
Frequency, #/h/sow	1.4	2.0	2.1	0.25	0.15
Total duration, sec/h/sow	52.0[a]	86.4[ab]	116.2[b]	20.11	0.05

[c,d] Means without a common superscript within a row tend to differ ($P < 0.10$).
[a,b] Means without a common superscript within a row differ ($P < 0.05$).
LS means of the Glimmix Procedure of the SAS. Pen was the experimental unit.
There were no interactions between the dietary treatment and parity ($P > 0.10$).
Data presented in the table are the aggressive interactions involving focal sows

Table 3. Aggressive interactions among dry sows during the first 72 h after grouping

	Time After Mixing					*P*-value
	0-6 h	6-24 h	24-48 h	48-72 h	SE	
# of Pens	8	8	8	8		
# of focal sows/pen	6	6	6	6		
Head-to-head knocking						
Frequency, #/h/sow	1.6[cd]	1.0[c]	1.1[cd]	2.3[d]	0.34	0.06
Total duration, sec/h/sow	7.6[cd]	4.4[c]	4.7[cd]	9.2[d]	1.37	0.06
Head-to-body knocking						
Frequency, #/h/sow	2.0[a]	0.5[b]	0.7[b]	0.8[b]	0.20	<0.001
Total duration, sec/h/sow	9.7[a]	2.5[b]	3.7[b]	5.0[b]	1.14	<0.001
Parallel pressing						
Frequency, #/h/sow	3.9[a]	1.0[b]	1.2[b]	1.3[b]	0.27	<0.001
Total duration, sec/h/sow	192.3[a]	72.4[b]	34.0[b]	40.7[b]	23.57	<0.001

[c,d] Means without a common superscript within a row tend to differ ($P < 0.10$).
[a,b] Means without a common superscript within a row differ ($P < 0.05$).
LS means of the Glimmix Procedure of the SAS. Pen was the experimental unit.
There were no interactions between the dietary treatment and the time period ($P > 0.10$).
Data presented in the table are the aggressive interactions involving focal sows

Table 4. Effects of dietary Trp supplementation on injury scores caused by aggression

	Dietary Trp treatment			P-value
	Control	Trp	SE	
# of pens	4	4		
# of sows/pen	22.5	24.3	2.80 (SD)	
Before grouping				
Head and shoulders	0.4	0.5	0.14	0.40
Body	0.1	0.3	0.11	0.25
Total	0.6	0.8	0.12	0.05
After grouping				
Head and shoulders	3.2	4.4	0.84	0.32
Body	2.3	3.1	0.61	0.39
Total	5.5	7.5	1.42	0.34
Injury caused by aggression				
Head and shoulders	2.8	3.9	0.81	0.38
Body	2.2	2.8	0.68	0.56
Total	5.0	6.7	1.46	0.45

LS means of the Glimmix Procedure of the SAS. Pen was the experimental unit.

Table 5 Effects of parity on injury scores caused by aggression at grouping

	Parity of sows				
	Parity 1	Parity 2	Parity 3+	Pooled SE	P-value
# of pens	8	8	8		
Ave. # of sows in each parity/pen	6.7	5.2	10.9		
Before grouping					
Head and shoulders	0.4	0.5	0.4	0.14	0.78
Body	0.1	0.3	0.2	0.10	0.16
Total	0.5	0.8	0.6	0.15	0.27
After grouping					
Head and shoulders	4.4[a]	4.1[ab]	2.8[b]	0.064	0.03
Body	2.9	2.8	2.4	0.46	0.19
Total	7.4[a]	6.9[ab]	5.2[b]	1.09	0.03
Injury caused by aggression					
Head and shoulders	4.0[a]	3.6[ab]	2.4[b]	0.67	0.05
Body	2.8	2.5	2.2	0.52	0.21
Total	6.8[a]	6.1[ab]	4.6[b]	1.13	0.04

[a,b] Means without a common superscript within a row differ (*P* < 0.05).
LS means of the Glimmix procedure of the SAS. Pen was the experimental unit.
There were interactions between Trp supplementation and parity (P > 0.10).

Table 6. Effects of dietary Trp on salivary cortisol concentrations of dry sows at grouping

	Before grouping		After grouping			P-value		
	Control	Trp	Control	Trp	SE	Diet	Grouping	Interaction
# of pens	4	4	4	4				
# of focal sows/pen	6	6	6	6				
Cortisol (ng/ml)	0.96[a]	1.14[a]	7.72[b]	10.37[b]	1.27	0.31	<0.001	0.37

[a,b] Means without a common superscript within a row differ (*P* < 0.05).

LS means of the Glimmix procedure of the SAS. Pen was the experimental unit.

Table 7. Effect of parity on salivary cortisol concentrations of dry sows at grouping

	Before grouping			After grouping				P-value		
	Parity 1	Parity 2	Parity 3+	Parity 1	Parity 2	Parity 3+	SE	Parity	Grouping	Interaction
# of pens	8	8	8	8	8	8				
# of focal sows/pen	2	2	2	2	2	2				
Cortisol (ng/ml)	1.37[a]	0.95[a]	0.96[a]	9.00[b]	11.45[b]	8.68[b]	1.46	0.59	<0.001	0.50

[a,b] Means without a common superscript within a row differ (*P* < 0.05).

LS means of the Glimmix procedure of the SAS. Pen was the experimental unit.

Table 8. Effects of supplementation of dietary tryptophan on sow performance

	Dietary Trp treatment			P-value
	Control	Trp Suppl.	χ^2	
No. of sows weaned[1]	94	98	0.88	0.81
No. of sows bred[1]	88	80	1.57	0.67
No. of sows farrowed[1]	57	49	0.22	0.64
Breeding rate[1], %	93.6	81.6	6.3	0.01
Farrowing rate[1], %	64.8	61.3	0.22	0.64
			SE	
Ave. parity of sows[2]	3.4	3.1	0.34	0.42
Litter size[2], piglets/litter				
Total born	10.5	12.6	0.54	0.01
Born alive	9.7	10.9	0.44	0.05
Stillborn	0.7	1.5	0.20	0.01

1. Frequency Procedure with Chi-square test.
2. LS means of the Glimmix procedure of the SAS with individual sow as the experimental unit.