Physiology, Immunity, Stereotyped Behavior, and Production Performance of the Lactating Sows in the Enriched Environment

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ABSTRACT

The main purpose of this enriched environment test was to determine that enriched environment with straw could eliminate or alleviate stress, improve immunity, reduce stereotyped behavior and improve production performance and other welfare levels of lactating sows. This study selected 48 produced 5-parity sows (Landrace male × Large White female) that has been reared separately in the general space without a enriched environment with straw (C, n = 24) as compared with the space utilizing the enriched straw environment (S, n = 24). Saliva was collected and tested for the density of cortisol at the following time-points: -15 min, and then at + 15, 30, 60, 90, 120, 180 and 240 min after the ACTH stimulation test at 1, 21, 28 and 35d post-partum. In addition, sera specimens were collected for the determination of the levels of prolactin, TNF-α and IL-6 at the 1st, 3rd and 5th week post-partum. Next, we observed sham-chewing food behavior , recorded production of the sows after weaning estrus interval data and statistics during the text weeks. The results showed that prolactin, TNF-α, IL-6 and other physiological indicators for each week determined were no significantly different ($P>0.05$). There were statistical differences observed ($P = 0.033$, and $P = 0.042$) in terms of sham-chewing behavior at the 4th and 5th week post-partum. Other production performance parameters were insignificant ($P > 0.05$) with the notable exception of the number of piglets that died within three days post-partum ($P = 0.032$). In conclusion,

enriched environment with straw could reduce the sham-chewing behavior of sows in the absence of food, but could not eliminate chronic stress in the late lactation. However, enriched environment had less influence on immunity and production performance indicators for the lactating sows.

INTRODUCTION

At present in China, restricted farrowing crate are used widely for lactating sows. Although the restricted farrowing crate can reduce the likelihood of the death of the piglet from the treading and compression actions of the sows, there are many welfare issues with regard to production. For example, the incidence of the disease of limb of the sows and reproductive disorders that are caused by body position and restricted movement, increase for sows, as does an increase the stereotype behavior of sows.[1] In addition, according to the statistical results of the past decade in the UK, studies showed thnumbersat the mode of relying on the restricted farrowing crates to improve the rate of survival in piglets had become increasingly challenging.[2] Therefore, several studies have led to an increased interest in loose-housing systems for lactating sows.[3] However, many of these studies have mainly examined nest-building behaviors, maternal behaviors and changes in animal postures.[4,5]

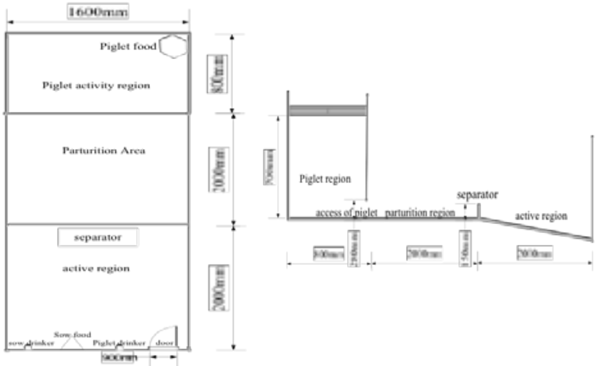
Since the hypothalamic, pituitary, adrenal (HPA) axis may be adapted to long-term stress, serum cortisol levels cannot be completely relied upon as an indicator of chronic stress.[6] Therefore, to accurately assess the impact of enriched environment on the welfare of the lactating sows, this study combined analyses of ACTH stimulation of cortisol in the saliva in an attempt to evaluate whether enriched environment can eliminate or relieve stress of sows.[15]

Prolactin is important for sows since it initiates and maintains maternal and breast-feeding behavior; however, the expression of maternal and breast-feeding behavior are not only influenced by genetic factors, but are also influenced by environment factors.[20] Hence, whether the environment can affect or correct the levels of prolactin remain unknown. These are of course important variables that might influence maternal and breast-feeding behavior, and further study is required to determine the specific interplay of environmental factors. However, relatively few studies have focused on the effect of enriched environment on prolactin in sows during the late lactation. Thus, our current study was mainly aimed at determining the effect of different puerperal enriched environment levels on prolactin at the fifth week post-partum in lactating sows, with the intention of determining the relationship between the levels of observed prolactin and the associated enriched environment.

Since there is a close relationship between the immune system and the HPA axis, the response of the immune system to stress is an adaptive mechanism that mammals have developed to cope with challenging situations. Furthermore, an insufficient adaptation can lead to reduced immune competence and increased disease susceptibility.[9] Therefore, to fully explore the effects of two different puerperal environments on sow welfare in more detail, the assay of serological IL-6 and TNF-α has proven to be useful.[10] Thus, it is necessary to increase our current understanding with regard the complexity of the relationship between stressful events and immune function during the period of late lactation. Moreover, there is a growing interest in the assessment of psychosocial stress in farm animals to improve our understanding of the welfare and health outcomes of farm animals.

The extent to which enriched environment affects animal behavior is an important consideration in lactating sows since it can influence the welfare of animals on the loose in the farrowing crate.[4,11] In addition, stereotypic behavior of animals is a type of mechanistic countermeasure in barren environments, or it might manifest as a reaction of animals to bad welfare.[12] Some scholars think that stereotypic behavior might occur transiently, and can simply correct enriched environment. Thus, the current study selected two different environments to observe the sham-chewing behavior of sows without food. The main aim of this study was to detect whether enriched environ-

Figure 1. *Schematic drawing of farrowing pen*



of the farrowing pen was 80 cm wide and 1200 cm high. There was a low barrier to prevent the piglets from leaving the rest areas during the first 3 days after birth. The piglets' feeding trough was 20 cm high. The feeding trough was 60 cm wide. The ground inside the farrowing pens was covered with concrete, which were then covered with straw. The straw was provided weekly. The sows were fed twice daily (at 07:30 h and 16:00 h) in the farrowing pens. The health of the piglets was checked, and the number of piglets experiencing diarrhea and swelling were recorded, and sick piglets were picked out at 06:30 h daily each morning. Approximately 2 cm of bedding was added to the floor of the farrowing pens at 07:30h each weekend.

ment could reduce the expression of stereotypic behavior.

It is generally thought that providing more space can increase production performance of sows. However, the effects of the barn environment on production performance among different research results are contradictory.[13] Thus, the impacts of enriched environment on production performance for lactating sows need to be further evaluated in China.

MATERIALS AND METHODS

Animals

Forty eight Landrace × Large white sows were selected and mated with Duroc (Canadian) males. Backfat and weight of the Landrace × Large white sows had no significant difference when mating (17.59±1.22 vs 18.06±0.91; 213.39±6.10 vs 215.69±5.01 kg) at the age of 7-8 months. They were fed in the same pig pen (5.7 m width, and 4.5 m length, which contained 10 pregnant sows). The ground was made of concrete and was covered with straw. There were three water sources that were used for natural ventilation for the pregnant sows during pregnancy. Sows were transferred to the farrowing pens 7 days before the expected due date. Twenty-four sows were randomly assigned to the parturition house with straw (C), and the other sows were randomly assigned to the farrowing pen without straw (S).

Housing and Management

The design of the farrowing pens are presented in Fig. 1. The inside of the farrowing pens was 4800 mm long, and 1600 mm wide. The door

The gilts were fed 3kg/day pre-parturition, and the quantity of feed was reduced by 0.5 kg/day in the week before farrowing. On the first day after delivery, the sows were fed 0.5 kg. On the following days each feed was increased by 0.5 kg until the gilts could feed ad-libitum. After weaning and until mating, the feeds of the primiparous sows were decreased to 3 kg per day. All the gilts were restrictively fed with complete feed. The feed contained the following constituents per kg feed: 12.9 MJ ME, 185.0 g crude protein, 50.0 g crude fat, 80.0 g crude ash, and 12.0 g lysine. During the study period, the temperature and relative humidity of the interior and exterior of the farrowing pens were measured daily with a hygrothermograph (Kestrel 4000 Pocket Weather Tracker; Kestrel, Santa Cruz, CA, USA). The daily temperature and humidity inside the farrowing pens were measured at 08:00 h (16.5 ◦C; 90.0%), 14:00 h (30.5 ◦C; 30.4%) and 20:00 h (21.6 ◦C; 58.7%) in August, and the conditions were measured at 08:00 h (8.7 ◦C; 85.5%), 14:00 h (33.0 ◦C; 20.3%) and 20:00 h (14.7 ◦C; 51.3%) in September.

Adrenocorticotropic Hormone (ACTH) Stimulation Test

Table 1. *Effect of the provision of straw on sow physiology at different stages.*

physiological indexes	environment	after the 1st delivery week	after the 3rd delivery week	after the 5th delivery week
IL-6 pg/ml	enriched environment	$253.00^{a}\pm8.01$	$260.04^{a}\pm5.55$	$233.16^{b}\pm7.56$
	general environment	$260.25^{a}\pm8.56$	$263.45^{a}\pm5.68$	$230.97^{b}\pm4.65$
TNF-α pg/ml	enriched environment	$137.02^{a}\pm10.56$	$129.60^{a}\pm12.32$	$123.94^{b}\pm10.21$
	general environment	$141.81^{a}\pm11.02$	$135.72^{a}\pm12.50$	$124.51^{b}\pm10.32$
prolactin ng/ml	enriched environment	$1.52^{a}\pm0.22$	$0.97^{b}\pm0.15$	$0.89^{c}\pm0.19$
	general environment	$1.49^{a}\pm0.20$	$0.94^{b}\pm0.15$	$0.84^{c}\pm0.13$

Note: Different superscripts in a row indicate significant differences between observation days (a, b. c: $P<0.05$). Different superscripts in a column indicate significant differences between breeds (x, y: $P<0.05$). Means and standard errors of the mean are shown.

Synthetic ACTH (Ser - Tyr - Ser - Met - Glu - His - Phe - Arg - Trp - Gly - Lys - Pro - Val - Gly - Lys - Lys - Arg - Arg - Pro - Val - Lys - Val - Tyr - Pro), was diluted with 0.9 % sterile saline, and ear marginal vein injection was done (dose of 10 pg/kg).14 Saliva was collected and tested for the levels of cortisol in -15 min, and at +15, 30, 60, 90, 120, 180, and 240 min after the ACTH stimulation test at 20, 27, and 34 days post-partum.15 Plasma concentrations of interleukin (IL6), tumor necrosis factor-a (TNF-α) and Prolactin in 1st, 3th, and 5th week after parturition, were measured by using a commercial porcine ELISA kit (Jiangcheng, China).

Behavioral Observations

The behaviors of the sows were recorded by a video surveillance system (Hikvision DS-IT5, China) for data acquisition to prevent artificially delimited observation times from impacting the test results. From the first to the fifth week postparturition, sham-chewing (i.e., chewing actions performed in the absence of food in the oral cavity – the definition of which, was quoted from Hurnik)16 was recorded on video with focal sampling continuous recording from 07:00 to 09:00 h and 13:00 to 15:00 h on the third and sixth day of each week.

Production Performance

Records were taken of all sows farrowing times, farrowing interval, the number of demised piglets within 3 post-partum days, the twenty-first weight of the piglet, the weight of the weaning piglet, and the sows estrous interval after weaning, following which, statistical analyses were made, and the weighing times were made during 06:00 – 07:00 h.

Statistical Analysis

Experimental data was analyzed by SPSS v.15.0 software. Behavioral data used One-Sample Kolmogorov-Smirnov analysis downloaded by non-parametric tests to process normality of the data. If the data was found to be not normally distributed, an algorithm was used such as arcsine, square root, or reciprocal of the data to correspond conversion of the data.

The multivariate procedure that was downloaded by GLM was used to analyze the effect of environmental treatment and different stages of production for sows on physiological and immune indices and the effect of different stages of post-partum for sows on the expression of chewing behavior without food, which was analyzed by LSD for multiple comparisons.

One-way ANOVA was used to analyze the effect of environmental treatment on production performance, and multivariate analysis downloaded by GLM was used to analyze the effect of environmental treatments on the weight of sows at different stages.

RESULTS

ACTH stimulation test

By the 21st day post-partum, the concentrations of cortisol at each time point showed no significant changes, but the cortisol levels return to normal levels when on the 28th and 35th day the saliva cortisol levels rose rapidly

Table 2. *Effects of feeding method on reproductive performance of sows*

production quota	group		P-value
	enriched environment (n=24)	general environment (n=24)	
farrowing time min	145.5±4.50	156.2±4.80	0.201
farrowing interval min	18.4±2.30	20.5±2.80	0.080
the death of piglets within 3 postpartum days	2.4^{a}±0.23	2.7^{b}±0.25	0.032
the weight of piglets on 21th day kg	5.2±0.10	5.47±0.10	0.601
weaning weight kg	8.2±0.15	8.11±0.15	0.120
sow oestrus interval d	4.5±0.50	5.0±0.50	0.310

Note: Different superscripts in a row indicate significant differences between observation days(a,b.c:P<0.05).

after administration of ACTH. However, there was no significant difference for sows at each point in terms of both of the environments. It is shown the basic trends in saliva cortisol levels after postnatal days 28 and 35 of the ACTH stimulation test.

Physiological Indexes

As Table 1 shows, the concentration of serum prolactin, IL-6 and TNF-α in sows were not significantly different (P>0.05) in different puerperal environments at the 1st, 3rd, and 5th weeks post-partum weeks. With prolonged lactation, the content of serological prolactin decreased gradually, and IL-6 was found to initially increase and then decrease, while the trend in the levels of TNF-α decreased.

Sham-Chewing Behavior Without Food

After the 2nd and the 3rd week post-partum, there was no significant difference in sham-chewing behavior of sows in the farrowing pen irrespective of the availability of straw. The 2nd week: 19.38±5.04 vs 18.43±2.55, p>0.05. The 3th week: 23.54±6.49 vs 22.70±2.67, p>0.05. After the 4th and 5th postpartum week, the 4th week: 38.59±4.23 vs 17.17±3.16, p<0.01, the 5th week: 42.65±5.84 vs 20.83±4.50, p<0.05.

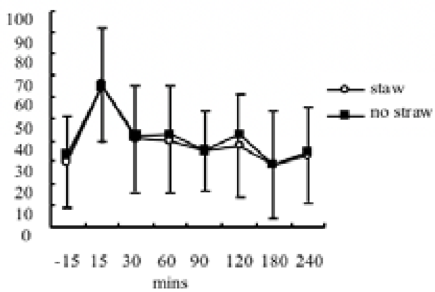
Production Performance

The result that the production performance of sows in enriched environment with straw is shown in Table 2. Mortality within 3 days post-partum was not significantly different, and the addition of straw did not significantly affect farrowing time, farrowing interval, death of piglets from the 4th post-partum day to weaning day, weight of piglets on the 21st day, weaning weight, and sow estrous interval after weaning.

DISCUSSION

The result of ACTH stimulation showed that there was a state of chronic stress during the late lactation period for sows that were given spacious enriched environment with straw. We speculated this may cause anxious chronic stress because of the impulsive behavior of piglets on sows. Further, adding straw did not exert a major effect on remitting stress during the late lactation period, which mostly agreed with previously published work.[4,11] Past research studies showed that at the 28th and 29th

Figure 2. *Graph showing the time course of the cortisol response to a ACTH stimulation test for the different treatments on day 35 (means ± standard error).*



days post-partum, limiting the interaction of sows with piglets together by force provokes conditions of stressful experience in sows.

In this experiment, the serological levels of IL-6 in lactating sows during the 1st, 3rd, and 5th weeks were not significantly different in the two different environments, which shows that irrespective of adding straw, the main elements of the humoral immune response cannot be induced or beneficially modulated in lactating sows. As compared with previously published studies,[17] we speculate that the pig's living space size may not be related to individual sow's fitness. The serological levels of IL-6 showed a decreasing trend after having first increased in secretion. However, this observation differed from previously published work where serological levels of IL-6 were decreasing or had plateaued over time.[9] A possible reason for this differential observation might have been due to the functional activity of IL-6 displaying both pro- and anti-inflammatory properties.[18] In addition, the existing insensitivity of plasma IL-6 levels to stress release might have also been associated with the anti-inflammatory action of IL-6 in this study, which can increase a beneficial compensatory adjustment of inflammatory cytokines adapting to the environment during the late lactation period.[19,20] However, in the 5th week post-partum, combined with the test results, we conclude that persistent stress can lead to a depressed immune system of the sows, which demonstrates that the fifth week of lactation in a stressful environment could threaten the health of lactating sows in two different enriched environments. Therefore, such changes in cell distribution may also reflect the psychological component of the stressor characterized by uncontrollability and unpredictability of the situations with anxiety.[21]

In this experiment, the serological levels of TNF-α for lactating sows at the 1st , 3rd, and 5th post-partum week were similar in the two different environments, which suggests that whether or not straw is added cannot influence the main elements of the lactating sows' humoral immune responsiveness. However, with prolonged lactation, the serological levels of TNF-α gradually decreased in sows under conditions of stress – an observation that is quite concordant with previously published data.[22] A possible explanation for stress-induced modulation of lymphocyte distribution may be an adaptive response that initiates enhanced immune surveillance to prepare the host for potential danger.[23] Thus, the present findings emphasize the particular importance of TNF-α in mediating the adaptive immune response to short-term psychosocial stress of the sows.

Additionally, TNF-α and IL-6 are important in host immune regulation. For example, TNF-α can induce Th1-type T-cell differentiation, and is a major factor in mediating cellular immunity. Also, IL-6 is predominantly secreted by differentiated Th2-type T-cells, and serves predominantly to mediate humoral immunity (Jarvis et al., 1997).[5] In general, Th1-type effector T-cells, and Th2 effector T-cells secreting factors that restrict each other's function in inflammation and host immunity, and in doing so, maintain immunological homeostasis at the levels of normal cellular and humoral immune competence and functional dynamic balance.[24] In our study, we found that both TNF-α and IL-6 secretion by sows showed a decreased trend under conditions of exposure to both kinds of environment, this function that eases the potential impact of chronic stress at the third week of post-partum in lactating sows. The consequence of this adjustment is realignment of the functional competence of either a Th1 or Th2-mediated immune response in the blood. This might also demonstrate that the lactating sow exposed to both environments gradually adapted to environment stress in the period of late lactation, which could serve to dampen the potential of biological and physiological damage.

From the observed results of sham-chewing behavior in this study, the spacious post-partum environment with straw can reduce stereotypic behaviors in late lactation. This observation shows that straw can maintain stable behaviors in the sow – an observation that is concordant with previously published work[1,25] in which it was found that a lack of straw strongly increased sham-chewing in sows, although the overall occurrence of this behavior in this study was low (i.e., less than 5% of the observation time).

The post-partum lasting time of sows is also one of the most important factors that can influence piglets survival. As the post-partum duration gets longer, the order of piglet birth will impart greater health risks to those piglets at the end of the birthing sequence.[26] Many studies have attempted to calculate the farrowing time and interval, and found that the farrowing time usually ranged from 156 to 262 min, and the delivery interval usually ranged from 15.2 to 22.4 min.[27] In our work, the scope of post-partum lasting time for sows in the two different environments was concordant with the aforementioned studies. It was reported that the mortality rate of piglets in the first 72 hours postpartum accounted for 75% of the total mortality before weaning.[28]

In our studies, adding straw improved upon piglet mortality over the period of 3 post-partum days, which showed that adding straw can reduce piglets mortality up to 72 h post-partum in the spacious post-partum environment. Generally the 21-day weight as sow lactation capacity, from this test result, the 21-day weight and weaning weight of piglets were no different on average. Thus, we speculated that adding a straw enriched environment plan would have no effect on sow lactation – a hypothesis that differs from the observations of other researchers.[29] We believe that the reason for this difference might be associated with sample quantity and the construction of the farrowing crate. To more accurately confirm the effect of straw on lactation, we also needed to enlarge the sample quantity to enable further studies. From the data obtained for sow estrus intervals, we noted that straw did not markedly influence post-partum estrus, so we speculate that sow post-partum estrus is not influenced by post-partum enriched environment, but instead, might be effected by nutrition and farrowing space. Precisely which factors are the most influential requires further detailed study.

CONCLUSION

In conclusion, the practice of enriched environment can reduce stress that is seen in sows, but it cannot eliminate the cause of chronic stress seen in sows, and it cannot as yet, improve the level of protective and adaptive host immunity. In addition, enriched environment can effectively reduce sham-chewing behavior, but the influence on production performance of sows still needs to expand the sample size in additional field studies to verify the observations reported herein.

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