

Effects of Backfat Thickness in Late Gestation on Litter Performance and Placental Lipid Oxidation Metabolism in Sows (Postprint)

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Date: 2017-10-23T00:00:00+00:00

Abstract

This experiment aimed to investigate the effects of backfat thickness in late gestation sows on litter performance and placental lipid oxidative metabolism, to explore the relationship between fat deposition during gestation and reproductive performance in sows. Backfat thickness was measured on day 109 of gestation in 846 multiparous Large White sows, which were divided into three groups: Group 1 with backfat thickness ≤ 18 mm (192 sows), Group 2 with backfat thickness of 19–22 mm (265 sows), and Group 3 with backfat thickness ≥ 23 mm (389 sows). Litter performance was recorded after farrowing, and lipid levels, oxidative product levels, and antioxidant enzyme activities were determined in placental tissues. The results showed: 1) Although backfat thickness in late gestation had no significant effect on total litter size, number of live-born piglets, or mummy count ($P > 0.05$), it significantly affected the number of stillbirths, litter birth weight, individual birth weight, and placental efficiency ($P < 0.05$). Among these, Group 2 had significantly higher individual birth weight, litter birth weight, and placental efficiency than the other two groups ($P < 0.05$); the number of stillbirths in Group 2 was significantly lower than in Group 1 ($P < 0.05$), with no significant difference from Group 3 ($P > 0.05$). Notably, backfat thickness in late gestation significantly affected the number of piglets per litter with birth weight ≤ 0.9 kg and the number of piglets per litter with birth weight ≥ 1.0 kg ($P < 0.05$), with Group 3 having significantly higher numbers of both categories than the other two groups ($P < 0.05$). 2) In the placental tissues of Group 3, not only were the levels of triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and free fatty acids (FFA) significantly higher than in the other two groups ($P < 0.05$), but the levels of malondialdehyde (MDA) and reactive oxygen species (ROS) were also significantly higher ($P < 0.05$), while superoxide dismutase (SOD) activity was significantly lower than in the other two groups ($P < 0.05$). 3) ROS levels in placental tissues of sows in late gestation showed a significant negative correlation with total litter

size, litter birth weight, and placental efficiency ($P < 0.05$), while MDA levels showed a significant negative correlation with litter size ($P < 0.05$). Therefore, backfat thickness in late gestation is closely associated with litter performance in sows. Maintaining backfat thickness at 19–22 mm during late gestation can result in higher litter performance; backfat thickness ≤ 18 mm increases the number of stillbirths; while backfat thickness ≥ 23 mm leads to excessive lipid deposition in placental tissues, thereby exacerbating placental oxidative stress.

Full Text

Preamble

Effects of Backfat Thickness of Sows at the End of Gestation on Litter Performance and Placental Lipid Oxidative Metabolism

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Abstract: This study aimed to investigate the effects of backfat thickness of sows at the end of gestation on litter performance and placental lipid oxidative metabolism, thereby exploring the relationship between fat deposition and reproductive performance in gestating sows. Backfat thickness was measured in 846 multiparous Large White sows on day 109 of gestation and divided into three groups: Group 1 (192 sows) with backfat thickness ≤ 18 mm, Group 2 (265 sows) with backfat thickness of 19–22 mm, and Group 3 (389 sows) with backfat thickness ≥ 23 mm. Litter performance was recorded after farrowing, and levels of lipids, oxidation products, and antioxidant enzyme activities were determined in placental tissues. The results showed that: 1) Although backfat thickness at the end of gestation had no significant effect on total number of piglets born, number born alive, or mummy number ($P > 0.05$), it significantly affected stillbirth number, litter weight at birth, piglet weight at birth, and placental efficiency ($P < 0.05$). Group 2 had significantly higher piglet weight at birth, litter weight at birth, and placental efficiency than the other two groups ($P < 0.05$), and significantly lower stillbirth number than Group 1 ($P < 0.05$), but did not differ significantly from Group 3 ($P > 0.05$). Notably, backfat thickness significantly affected the number of piglets per litter with birth weight ≤ 0.9 kg and ≥ 1.0 kg ($P < 0.05$), with Group 3 having significantly more of these low-birth-weight piglets than the other groups ($P < 0.05$). 2) In Group 3 placental tissues, levels of triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and free fatty acids (FFA) were significantly higher than in the other groups ($P < 0.05$). Moreover, malondialdehyde (MDA) and reactive oxygen species (ROS) levels were significantly elevated, while superoxide dismutase (SOD) activity was significantly reduced ($P < 0.05$). 3) Placental ROS level was

significantly negatively correlated with total number born, litter weight at birth, and placental efficiency ($P < 0.05$), while MDA level was significantly negatively correlated with total number born ($P < 0.05$). These findings indicate that backfat thickness at the end of gestation is closely associated with litter performance. Maintaining backfat thickness at 19–22 mm yields optimal litter performance; thickness ≤ 18 mm increases stillbirths, while thickness ≥ 23 mm causes excessive lipid deposition in the placenta and exacerbates placental oxidative stress.

Keywords: gestational sow; backfat thickness; litter performance; placenta; lipid level; oxidative stress

Introduction

Backfat thickness is an important indicator of sow body condition. Research has shown that abnormal sow body condition often leads to abortion, stillbirth, or intrauterine growth retardation (IUGR) [1–2]. The placenta serves as the direct interface between fetus and mother, maintaining pregnancy and embryonic development through nutrient transport, immune response participation, and hormone secretion [3–4]. Therefore, the placental environment directly affects fetal development. Previous studies have found that oxidative stress occurs during maternal pregnancy, and maternal obesity during gestation exacerbates oxidative stress responses in both mother and fetus, affecting fetal development [5–6]. Recent research indicates that maternal obesity also intensifies placental oxidative stress, stimulating the placenta to secrete various factors such as free radicals, oxidized lipids, cytokines, and soluble vascular endothelial growth factor receptors, all of which are significantly elevated under obese conditions and can impair placental function and fetal development [7]. Similar results have been observed in sheep [8] and baboon [9] models. Maternal body fat status during gestation is a key regulator of reproductive performance in sows, yet current reports are limited to studies on how gestational body condition affects placental efficiency in different breeds [10], and its relationship with the placental environment remains unreported. This study investigated the effects of backfat thickness at the end of gestation on litter performance and placental lipid oxidative metabolism to explore the relationship between gestational fat deposition and reproductive performance, providing a reference for rational backfat thickness control and standardized feeding practices in swine production.

Materials and Methods

1.1 Experimental Animals and Grouping

This experiment was conducted from August to November 2015 at Wuhan Jinlong Breed Farm in Hubei Province. A total of 846 normal pregnant multiparous Large White sows were selected and divided into three groups based on backfat thickness measured on day 109 of gestation: Group 1 (192 sows) with backfat

thickness \$ \$18 mm, Group 2 (265 sows) with backfat thickness of 19-22 mm, and Group 3 (389 sows) with backfat thickness \$ \$23 mm.

1.2 Feeding Management

Experimental sows received routine immunization according to the farm' s program and had free access to water. During gestation, sows were fed twice daily at 06:00 and 14:00, with daily feed amounts of 2.0-3.5 kg adjusted based on residual feed. During lactation, sows were fed three times daily at 06:00, 11:00, and 17:00, with daily feed amounts of 4.5-6.5 kg adjusted accordingly. Piglets were nursed by sows after farrowing.

1.3 Sample Collection and Methods

Based on breeding records, sow ear tags, breed, parity, and boar information were documented. Sows entered the farrowing house 7 days before expected farrowing and were monitored 24 hours daily for parturition assistance.

1.3.1 Backfat Thickness Measurement Backfat thickness on day 109 of gestation was measured using a Renco ultrasound device (USA). The procedure was as follows: the measurement site was identified at 6.5-7.0 cm from the dorsal midline on the last rib; hair was clipped, liquid paraffin applied, and the probe placed on the site after calibrating the device. Three consecutive readings were recorded and averaged [11].

1.3.2 Sample Collection and Determination Based on parity and breed, 18-20 sows were randomly selected from each group for placental sampling. Placentas were collected and weighed at farrowing, the number recorded, and samples taken from the area around the umbilical cord were immediately stored at -20°C. Litter performance parameters including total number born, number born alive, mummy number, stillbirth number, piglet weight at birth, and litter weight at birth were recorded. The number of piglets per litter with birth weight \$ \$0.9 kg and \$ \$1.0 kg was also counted. Placental efficiency was calculated as the ratio of piglet weight at birth to placental weight [12].

1.4 Determination of Related Indices

Placental tissue (0.1 g) was homogenized in 1 mL physiological saline. Enzymatic methods were used to determine total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C) levels. Xanthine oxidase method was used for superoxide dismutase (SOD) activity, thiobarbituric acid method for malondialdehyde (MDA) content, ferric ion method for total antioxidant capacity (T-AOC), dithiobisnitrobenzoic acid method for glutathione peroxidase (GSH-Px) activity, ammonium molybdate method for catalase (CAT) activity, and enzyme-linked immunosorbent assay for free fatty acids (FFA)

and reactive oxygen species (ROS) levels. FFA and ROS assay kits were purchased from Hubei Chengqian Biotech Co., while other kits were from Nanjing Jiancheng Bioengineering Institute.

1.5 Statistical Analysis

Data were compiled using Excel 2003. One-way ANOVA was performed using the GLM procedure of SAS 8.0 software, and Pearson correlation analysis was conducted. Significance level was set at $P < 0.05$.

Results

2.1 Effects of Backfat Thickness at the End of Gestation on Litter Performance

As shown in Table 1, no significant differences were observed among the three groups in total number born, number born alive, or mummy number ($P > 0.05$). However, Group 1 had significantly higher stillbirth number than the other two groups ($P < 0.05$), while Group 2 and Group 3 did not differ significantly ($P > 0.05$). Backfat thickness significantly affected litter weight at birth, piglet weight at birth, number of piglets per litter with birth weight $\$ 0.9$ kg, and number with birth weight $\$ 1.0$ kg ($P < 0.05$). Group 2 had significantly higher litter weight at birth than Group 1 ($P < 0.05$) and significantly higher piglet weight at birth than both other groups ($P < 0.05$). Group 3 had significantly more low-birth-weight piglets ($\$ 0.9$ kg and $\$ 1.0$ kg) than the other groups ($P < 0.05$), which did not differ from each other ($P > 0.05$). Placental weight and placental efficiency were also significantly affected ($P < 0.05$). Groups 1 and 2 had significantly lower placental weight than Group 3 ($P < 0.05$). Placental efficiency differed significantly among all three groups ($P < 0.05$), being highest in Group 2 (4.93) and lowest in Group 3 (4.57).

2.2 Effects of Backfat Thickness on Placental Lipid Levels

As shown in Table 2, no significant differences were observed among groups in placental TC level ($P > 0.05$). However, Group 3 had significantly higher levels of TG, LDL-C, and FFA than the other two groups ($P < 0.05$), which did not differ significantly from each other ($P > 0.05$).

2.3 Effects of Backfat Thickness on Placental Lipid Oxidative Metabolism

As shown in Table 3, backfat thickness had no significant effect on placental T-AOC or CAT and GSH-Px activities ($P > 0.05$). However, Group 3 showed significantly higher ROS and MDA levels and significantly lower SOD activity than the other two groups ($P < 0.05$), which did not differ significantly from each other ($P > 0.05$).

2.4 Correlation Analysis of ROS, MDA, SOD Activity with Litter Traits

As shown in Table 4, placental ROS level was significantly negatively correlated with total number born, litter weight at birth, and placental efficiency ($P < 0.05$), with correlation coefficients of -0.311, -0.305, and -0.295, respectively, but not with piglet weight at birth ($P > 0.05$). Placental MDA level was significantly negatively correlated with total number born ($P < 0.05$, $r = -0.286$) but not with litter weight at birth, piglet weight at birth, or placental efficiency ($P > 0.05$). Placental SOD activity was not significantly correlated with any litter performance traits ($P > 0.05$).

Discussion

This study demonstrates that maternal fat deposition at the end of gestation affects litter performance. Sows with backfat thickness of 19–22 mm at the end of gestation exhibited optimal performance, with significantly higher litter weight at birth and piglet weight at birth than those with backfat thickness \$ 18 mm or \$ 23 mm. Conversely, backfat thickness \$ 18 mm or \$ 23 mm increased stillbirths and weak piglets. This occurs because maternal body condition affects placental lipid levels and oxidative stress status. Particularly when backfat thickness exceeds 23 mm, excessive lipid deposition in the placenta and intensified oxidative stress become important factors reducing litter performance.

3.1 Effects of Backfat Thickness on Litter Performance

The relationship between gestational body condition and litter performance has long been of research interest. This study confirms that maintaining moderate backfat thickness (19–22 mm) at the end of gestation yields optimal litter performance, particularly with significantly higher piglet weight at birth and the highest placental efficiency compared to other groups. Previous research has confirmed that malnutrition during gestation impairs normal placental metabolism, reducing placental cell number, volume, and weight, leading to compromised placental function and increased abortion, premature birth, stillbirth, and low-birth-weight piglets [13]. Therefore, adjusting feed intake according to body condition to maintain appropriate fat deposition or backfat thickness is crucial for achieving good reproductive performance, with end-of-gestation body condition reflecting the cumulative result of gestational feeding.

This study found that compared to the 19–22 mm group, sows with backfat thickness \$ 18mmhad significantly more stillbirths and lower litter weight at birth and piglet weight at birth, consistent with *birth – weight piglets per litter* (\$0.9 kg and \$1.0 kg) was significantly higher, indicating increased IUGR incidence with excessive backfat thickness. IUGR causes include maternal malnutrition, overnutrition, disease, environmental stress, and abnormal placental function [16–17]. The concept of placental efficiency, proposed by Wilson et al. [12], measures the placenta's capacity to support fetal growth. This study found that Groups 1 and 3 had significantly

lower placental efficiency than Group 2, with Group 3 being even lower than Group 1, consistent with Yao Jiaojiao et al. [10]. This suggests that end-of-gestation body condition significantly affects placental nutrient transport capacity, with excessive fat deposition having a more pronounced negative impact. Therefore, IUGR in Group 3 may be related to compromised placental function. In summary, end-of-gestation nutritional status is closely related to placental function and affects piglet birth weight and IUGR incidence. As backfat thickness reflects nutritional status, managing sow body condition throughout gestation and rationally controlling backfat thickness are key to maintaining normal placental function and improving litter performance.

3.2 Effects of Backfat Thickness on Placental Lipid Oxidative Metabolism

As the medium for maternal-fetal nutrient transport, the placenta's lipid levels are also affected by maternal body condition at the end of gestation. Placental lipids are obtained through two pathways: maternal lipid transport and endogenous placental lipid metabolism. During late gestation, maternal fat lipolysis increases, and maternal cholesterol, LDL-C, and FFA can be transported to the placenta via placental receptors, while TG enters blood as lipoproteins and is hydrolyzed to FFA for placental transport [18-20]. Additionally, studies have found increased lipoprotein lipase activity in placentas of obese pregnant women, promoting fat hydrolysis to produce FFA that is then esterified to TG via fatty acid synthase [21]. The increased lipid levels in Group 3 placentas are consistent with Malti et al. [7], who reported significantly higher TG levels in maternal and placental tissues of obese pregnant women compared to controls. Therefore, excessive placental lipid deposition primarily results from excessive maternal body fat leading to increased FFA and other lipids transported to the placenta, coupled with enhanced TG synthesis via fatty acid synthase.

Meanwhile, this study also found increased oxidation products in Group 3 placentas, with significantly elevated ROS and MDA levels and reduced SOD activity. Increased oxidation products compromise the placental environment. Studies have reported that elevated lipid peroxidation product MDA causes vascular endothelial damage and abnormal placental vascular development, impairing fetal nutrient and gas exchange [22-23]. Low-density lipoprotein (LDL) is readily oxidized to oxidized LDL (ox-LDL), which promotes endothelial cell damage and inflammation [24]. Although this study did not measure ox-LDL levels, Group 3 had significantly higher LDL-C levels than the other groups. Correlation analysis further revealed that elevated placental ROS or MDA levels adversely affected litter performance. In conclusion, decreased litter performance in sows with excessive gestational fat deposition is mainly due to excessive placental lipid deposition intensifying placental oxidative stress and creating an unfavorable environment for fetal growth. Therefore, rationally controlling sow fat deposition is a key measure for maintaining a healthy placental environment and improving reproductive performance.

Conclusion

Backfat thickness at the end of gestation is closely related to litter performance. Maintaining backfat thickness at 19–22 mm yields high litter performance; thickness ≥ 18 mm increases stillbirths, while thickness ≥ 23 mm causes excessive placental lipid deposition and intensifies placental oxidative stress.

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