Effects of Dietary Monoglyceride and Diglyceride Supplementation on the Performance, Milk Composition, and Immune Status of Sows During Late Gestation and Lactation

Hanqing Song1†, Wei Chai†, Fei Yang1, Man Ren2,3, Fang Chen1, Wutai Guan1,4* and Shihai Zhang1,4*

1 Guangdong Provincial Key Laboratory of Animal Nutrition Control, College of Animal Science, South China Agricultural University, Guangzhou, China, 2 College of Animal Science, Anhui Science and Technology University, Fuyang, China, 3 Anhui Provincial Key Laboratory of Animal Nutritional Regulation and Health, Fuyang, China, 4 National Engineering Research Center for Breeding Swine Industry, College of Animal Science, South China Agricultural University, Guangzhou, China

Monoglyceride and diglyceride (MGDG) have antiviral and antibacterial properties and act as emulsifiers to increase dietary lipid digestibility. The primary aim of this trial was to investigate the effects of dietary MGDG supplementation on the reproductive performance and health status of sows during late gestation and lactation. One hundred sows (Landrace × Large White, mean parity of 4.59) were randomly allocated to groups receiving two different diets with 4% soybean lipids or 4% MGDG from day 85 of gestation to day 21 of lactation. Milk samples were collected on the day of farrowing (colostrum) and on day 14 of lactation, and blood samples were collected from the sows on days 0, 14, and 21 of lactation. Compared with control sows, sows fed MGDG showed no significant differences in reproductive performance ($P > 0.05$), but sow back fat thickness loss decreased during lactation ($P < 0.05$). There was a significant decrease in TNF-α concentrations in colostrum in the MGDG-supplemented sows compared with that in the soybean lipid-supplemented sows ($P < 0.05$). Dietary MGDG supplementation decreased sow plasma IL-8 concentrations on day 0 of lactation and IL-18 concentrations on days 14 and 21 of lactation ($P < 0.05$). Administration of MGDG increased the glucose and total cholesterol concentrations in sow plasma on day 14 and day 21, respectively ($P < 0.05$). The findings in this study suggest that MGDG supplementation could be effective in reducing back fat loss, decreasing inflammatory factor levels, and controlling total cholesterol (TCHO) concentrations during lactation.

Keywords: sow, monoglyceride and diglyceride, reproductive performance, milk composition, soybean lipids

INTRODUCTION

Monoglyceride (MG) and diglyceride (DG) are critical hydrolyzed products of dietary triglycerides. Under normal physiological conditions, the hydrolysis of dietary triglycerides starts from the stomach, and 5–40% of triglycerides are hydrolyzed by gastric lipase (1). These undigested triglycerides will be further hydrolyzed in the duodenum, which produces glycerols, MGs, DGs,
and free fatty acids (2, 3). After digestion, MGs, free fatty acids, and other lipids are associated with bile salts to form micelles for absorption.

MG and DG not only act as intermediate metabolites during triglyceride digestion but are also considered excellent water-in-oil (W/O)-type emulsifiers due to their specific amphiphilic molecular structures (hydrophilic glycerol radicals and lipophilic alkyl radicals). Emulsifying agents have been found to promote the incorporation of fatty acids into micelles and to increase the digestibility of fat when added to the diets of rats and chicks (4, 5). The carbon chain length of fatty acids has been proposed to affect the formation of micelles (6). It is more difficult for long-chain fatty acids (LCFAs) to form micelles than medium-chain fatty acids (MCFAs) and short-chain fatty acids (SCFAs). Soybean lipids are widely used in animal diets and are mainly composed of LCFAs. To enhance the digestibility of dietary lipids, supplementation with emulsifiers has been reported as an efficient way to enhance the formation of micelles (7). Currently, a cocktail of monoglycerides and diglycerides (MGDG) is widely used as an emulsifier and/or stabilizer in the food industry (8, 9). Therefore, monoglycerides and diglycerides (MGDGs) may be efficiently utilized as energy sources to relieve weight loss and improve animal production performance.

In addition, monoglycerides have been known for a long time to have strong antiviral and antibacterial properties (10, 11). Monolinolein is reported as a more efficient antibacterial compound than its corresponding fatty acids (12). The sites of action on bacteria are the cell wall and cell membrane. Monoglycerides are reported to be incorporated into the lipid membrane and cause destabilization of the bilayer (13). For instance, monoglycerides have antibacterial activities against *Helicobacter pylori* (14). Both monolinolein and monolinolenin have antibacterial activity against Group B *Streptococcus* (12). Intriguingly, the antimicrobial and antiviral activities of MG and DG are partially dependent on the nature of fatty acids (15).

Sufficient energy intake and less bacterial infection are critical for sows to maintain their productive performance during late gestation and lactation. Previously, it has been reported that lipids can be used to increase the energy available to the sow during gestation and lactation. The addition of lipids to sow diets attenuates weight loss and improves the weight gain and survival of piglets (16, 17). Because MGDG is easily digested and exhibits antibacterial properties, we propose that MGDGs may have beneficial effects on the health status of sows. The aim of this study was to investigate the effects of dietary MGDG supplementation on sow performance, back fat thickness, milk composition, and inflammatory factors during late pregnancy and lactation.

**MATERIALS AND METHODS**

**Animals and Experimental Design**
The experimental procedures followed a protocol approved by the South China Agricultural University Animal Care and Use Committee (No. 20110107-1, Guangzhou, China). One hundred multiparous sows (Large White × Landrace, mean parity of 4.59) were selected for the study. The sows were categorized by parity, backfat thickness, and historical reproductive performance before being randomly assigned to two dietary treatment groups, a control group (n = 50) and an MGDG group (n = 50), to ensure that these characteristics were balanced between treatments.

This trial was conducted from gestation day (G) 85 to lactation day (L) 21 at a commercial pig farm. The control group diet included 4% soybean lipids, and the MGDG group diet included 4% MGDGs (containing 40% monoglycerides and 50% diglycerides; Guangzhou Jiadele Nutrition Technology Co., Ltd., Guangzhou, China). From days 85 to 109 of gestation, all sows were managed in the same gestation facility, which was a semi-open building. On G109, all sows were moved to farrowing crates. During the entire experimental period, the sows were assigned to a pad/fan-cooled farrowing house (for active cooling, AC), and the sows within each dietary treatment were fed the same experimental diet during both late gestation and lactation.

**Diets and Management**
Each diet was formulated to meet or exceed the nutrient requirements of late gestating and lactating sows (18). Table 1 shows the diet compositions and nutrient levels. In the experimental diets, the 4% lipid source was either soy lipids or MGDGs. The fatty acid composition of the supplemental fat sources was analyzed by gas chromatography (GC-2010 Pro, SHIMADZU Corporation, Kyoto, Japan). Mono- and diglycerides were measured according to the AOAC official method ([19], 993.18). The fatty acid profiles of soy lipids and MGDGs are described in Table 2.

The experiment began on day 85 of pregnancy. At this time, the sows were individually housed in gestation crates with a solid concrete floor and had free access to drinking water. Approximately 1 week before parturition, the sows were moved into the environmentally controlled farrowing house and individually housed in farrowing crates (2.2 × 2.4 × 1.5 m³) with a solid concrete floor and a piglet creep area with a heating lamp. The sows and the piglets had free access to water.

During gestation, the sows were fed 3.0 kg/d. The sows were not fed on the day of farrowing. After farrowing, the feed supply was increased by 1 kg/d until day 3 and then by 0.5 kg/d until day 6 of lactation. Afterward, the animals were allowed *ad libitum* consumption of the lactation diet, which was adjusted for each sow depending on daily intake. No creep feed was offered to piglets during the experiment. Piglets were cross fostered in the same dietary treatment within 24 h of birth so that piglets of similar weight were brought together. The litter size was adjusted and maintained at 10–12 piglets per sow.

**Data and Sample Collection**

**Sow and Litter Performance**
At farrowing, the total number of piglets [the numbers of live, weak (BW <0.8 kg), stillborn, and mummified piglets] and the litter weights were recorded. At weaning, the number of pigs weaned and the litter weight were measured.
TABLE 1 | Ingredients and chemical compositions of the diets (as-fed basis).  

| Item                  | Control diet | MGDG diet |
|-----------------------|--------------|-----------|
| Ingredient (%)        |              |           |
| Corn                  | 43.8         | 43.8      |
| Soybean meal, 43.0% CP| 24.00        | 24.00     |
| Barley, 11.33% CP     | 10.00        | 10.00     |
| Wheat bran, 15.7% CP  | 6.00         | 6.00      |
| Wheat flour, 15.3% CP | 5.00         | 5.00      |
| Fish meal, 62.8% CP   | 2.00         | 2.00      |
| Soy lipids            |              |           |
| MGDG                  | 4.00         |           |
| Dicalcium phosphate   | 1.00         | 1.00      |
| Vitamin and mineral premix<sup>a</sup> | 4.00 | 4.00 |
| Mold inhibitor        | 0.20         | 0.20      |
| Total                 | 100.00       | 100.00    |

Nutrient composition, unit  

| Item             | Control diet | MGDG diet |
|------------------|--------------|-----------|
| DE, Mcal/kg      | 14.27        | 14.65     |
| ME, Mcal/kg      | 13.72        | 14.27     |
| NE, Mcal/kg      | 10.31        | 10.63     |
| CP, %            | 17.93        | 17.93     |
| EE, %            | 6.54         | 6.54      |
| CF, %            | 3.31         | 3.31      |
| Ca, %            | 1.00         | 1.00      |
| Total P, %       | 0.74         | 0.74      |
| Available P, %   | 0.50         | 0.50      |
| Lys              | 1.04         | 1.04      |
| Met + Cys        | 0.62         | 0.62      |
| Thr              | 0.68         | 0.68      |
| Trp              | 0.22         | 0.22      |
| Digestible Lys, %| 0.91         | 0.91      |
| Digestible Met + Cys, % | 0.51 | 0.51 |
| Digestible Thr, %| 0.57         | 0.57      |
| Digestible Trp, %| 0.19         | 0.19      |

<sup>a</sup>Per kilogram of complete diet, the vitamin and mineral premix supplied the following: vitamin A, 10,000 IU; vitamin D3, 3,600 IU; vitamin E, 100 IU; vitamin K3, 7.2 mg; vitamin B1, 3 mg; riboflavin, 10.8 mg; vitamin B2, 5.4 mg; vitamin B3, 0.06 mg; D-pantothenic acid, 36.0 mg; niacin, 60.0 mg; folic acid, 6 mg; biotin, 0.6 mg; copper, 10 mg (as CuSO4·5H2O); iron, 80 mg (as FeSO4·H2O); manganese, 30.0 mg (as MnSO4); zinc, 80.0 mg (as ZnSO4); selenium, 0.15 mg (as Na2SeO3); iodine, 0.14 mg [as Ca (IO3) 2]; and cobalt, 0.1 mg (as CoCl2·6H2O).

TABLE 2 | Fatty acid composition of the Soybean Lipids MGDGs.  

| Composition | Soybean lipids | MGDGs |
|-------------|----------------|-------|
| C16:0       | 11.96          | 4.16  |
| C18:1       | 23.83          | 2.54  |
| C18:2       | 52.71          | 25.17 |
| C18:3       | 4.81           | 0.76  |
| C18:0       | 4.02           | 6.37  |
| C16:0&C16:0 | –              | 0.76  |
| C16:0&C18:0 | –              | 4.02  |
| C16:0&C18:2 | –              | 6.49  |
| C18:1&C18:1-2 | –           | 16.42 |
| C18:2&C18:2-3 | –          | 22.43 |
| Others      | 2.67           | 0.98  |

The back fat thickness of the sow at the P2 point (6.5 cm from the middle line of the last rib) was measured using a real-time ultrasound facility (Renco Lean-meter, Renco Corporation, Minnesota, USA) on days 0 and 14 of lactation.

Sow Back Fat Thickness  
The back fat thickness of the sow at the P2 point (6.5 cm from the middle line of the last rib) was measured using a real-time ultrasound facility (Renco Lean-meter, Renco Corporation, Minnesota, USA) on days 0 and 14 of lactation.

Blood Sampling  
At farrowing, on L14 and at weaning, 10 mL blood samples were taken from 10 sows (near the average BW and parity in each treatment group) by ear venipuncture using heparinized Vacutainer tubes (Sanli Medical Technology Development Co., Ltd., Hunan, China). Plasma was harvested after centrifugation at 3,000 × g for 10 min. After collection, each plasma sample was divided into three 0.5 mL samples (pipetted into 1 mL frozen tubes and immediately frozen in liquid nitrogen for immunoglobulin analysis) and a 2 mL sample (transferred to a 4 mL centrifuge tube and then stored at −80°C for cytokine and blood parameter analysis).

Colostrum and Milk Sampling  
Colostrum and milk samples were taken from 10 sows (near the average BW and parity in each treatment group). Colostrum was sampled by hand expression from functional glands within 12 h post-partum without oxytocin injection. Fourteen-day milk was sampled after intramuscular injection of 20 IU oxytocin (Jiangxi Huiliqeng Bio-Technique Co., Ltd., Jiangxi, China). Approximately 30 mL of sample was collected each time. After collection, the colostrum or milk was divided into two 15 mL centrifuge tubes and stored at −80°C for nutritional composition, immunoglobulin, and cytokine analyses.

Chemical Analysis  
Colostrum and Milk Composition  
The colostrum and milk samples were tested for solids-not-fat, fat, protein, and lactose using a fully automated milk analyzer (ULTRAMILER-UL40AC, Hangzhou Ultrasun Technologies Co., Ltd., Zhejiang, China).

Immunoglobulin Concentrations  
The immunoglobulin A (IgA), immunoglobulin G (IgG), and immunoglobulin M (IgM) concentrations in colostrum and milk were analyzed by ELISA using pig immunoglobulin-specific kits (CUSABIO Biotech Company, Wuhan, China). Prior to analysis, the lipids in colostrum and milk were removed by centrifugation at 3,000 × g and 4°C for 20 min according to a method described previously (20). The ELISA procedure was as follows: (1) A blank well was prepared without any solution. (2) Fifty microliters of a standard or sample was added to each well. (3) Fifty microliters of HRP-conjugate was added to each well (not to the blank well). (4) The wells were incubated for 40 min at 37°C. (5) The wells were aspirated and washed 5 times. (6) Ninety microliters of TMB substrate was added to each well. (7) Fifty microliters of stop solution was added to each well. The wells were measured with a plate reader at 450 nm within 5 min.
Cytokine Concentrations
Tumor necrosis factor α (TNF-α), interleukin (IL)-8, and IL-18 levels in sow plasma, colostrum and milk were determined with ELISA kits (CUSABIO Biological Engineering Co., Ltd., Wuhan, China). The ELISA procedure was as follows: (1) One hundred microliters of a standard or sample was added to each well and incubated for 2 h at 37°C. (2) The liquid of each well was removed without washing. (3) Then, 100 µL of biotin-antibody (1x) was added to each well and incubated for 1 h at 37°C. (4) The wells were aspirated and washed 3 times. (5) Then, 100 µL of HRP-avidin was added to each well and incubated for 1 h at 37°C. (6) The wells were aspirated and washed 5 times. (7) Ninety microliters of TMB substrate was added to each well and incubated for 20 min at 37°C. (8) Fifty microliters of stop solution was added to each well. The wells were measured with a plate reader at 450 nm within 5 min.

Blood Parameter Concentrations
The concentrations of glucose (GLU), plasma urea nitrogen (PUN), triglycerides (TGs), total cholesterol (TCHO), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) in plasma were determined with commercial kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China). The procedure was as follows: (1) First, 2.5 µL of distilled water was added to the blank well. (2) Then, 2.5 µL of a standard or sample was added to each well. (3) A total of 250 µL of TMB substrate was added to each well. (4) The wells were incubated for 10 min at 37°C. (5) The wells were measured with a plate reader at 510 nm within 5 min.

Statistical Analysis
Reproductive and lactation performance, back fat thickness, and colostrum and milk composition were analyzed by independent-sample Student's t-tests using SPSS 22.0 (IBM-SPSS Inc., Chicago, Illinois, USA) after checking for normality and homogeneity of variance according to the Shapiro–Wilk and Levene tests, respectively. Plasma cytokine concentration and plasma constituent concentration data were analyzed using the mixed procedure of SAS with repeated measures. The model included diet (control vs. MGDG), parity number, and timepoint (defined as a repeated measure) and their interaction as fixed effects and a random effect. The results are expressed as the means and standard error means (SEMs). The effects of treatment on the presence or absence of estrus after weaning were evaluated using chi-square analysis (21). Probability values <0.05 were considered to indicate significance, and probability values <0.10 were considered to indicate tendencies toward differences between treatments.

RESULTS
Reproductive and Lactation Performance
The effects of dietary MGDG supplementation during late gestation and lactation on sow reproductive and lactation performance are shown in Table 3. The total number of piglets born, the numbers of stillborn and live-born piglets, the litter birth weights, and the individual piglet birth weights were unaffected by the treatment (P > 0.05; Table 3). The average daily feed intake (ADFI) and the estrus rate were not affected by MGDG supplementation (P > 0.05). The average daily gain (ADG), litter weight, average piglet weight, and preweaning survival during lactation were unaffected by the MGDG-supplemented diet compared with the control diet (P > 0.05).

Back Fat Thickness and Estrus Interval
The effects of dietary MGDG supplementation during late gestation and lactation on sow colostrum and milk composition are shown in Table 4. The loss of backfat thickness was significantly decreased after MGDG supplementation compared with the control group during lactation (P < 0.05; Table 4).

Colostrum and Milk Composition
The effects of dietary MGDG supplementation during late gestation and lactation on sow colostrum and milk composition are shown in Table 5. No differences between the treatment and control groups were found with regard to the protein and lactose levels in colostrum and milk (P > 0.05; Table 5). However, the sows with dietary MGDG supplementation tended to have higher fat concentrations in their colostrum than sows fed the control diet (P < 0.1).

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### Table 3 | Effects of dietary MGDG supplementation during late gestation and lactation on sow reproductive and lactation performance.

| Parameter | Control | MGDG | P-value |
|-----------|---------|------|---------|
| No. of sows | 50 | 50 | 0.634 |
| ADFI (day 0–day 21 of lactation), kg | 5.34 ± 0.08 | 5.26 ± 0.10 | 0.771 |
| Reproductive performance | | | |
| Total No. of pigs born/litter | 11.58 ± 0.37 | 12.20 ± 0.36 | 0.878 |
| No. of pigs born alive/litter | 10.92 ± 0.37 | 11.64 ± 0.36 | 0.133 |
| No. of stillbirths/litter | 0.46 ± 0.05 | 0.35 ± 0.07 | 0.270 |
| No. of weak pigs/litter | 0.43 ± 0.12 | 0.70 ± 0.13 | 0.134 |
| No. of mummies/litter | 0.07 ± 0.01 | 0.11 ± 0.003 | 0.122 |
| Litter birth weight, kg | 16.78 ± 0.53 | 16.89 ± 0.50 | 0.442 |
| Individual piglet weight, kg | 1.56 ± 0.13 | 1.47 ± 0.12 | 0.335 |
| Lactation performance | | | |
| No. of pigs after cross-foster | 10.34 ± 0.17 | 10.41 ± 0.15 | 0.686 |
| No. of weaning pigs | 9.44 ± 0.20 | 9.22 ± 0.21 | 0.481 |
| Preweaning survival, % | 91.58 ± 1.35 | 88.81 ± 0.98 | 0.270 |
| Individual pig weight after cross-foster, kg | 1.96 ± 0.55 | 1.90 ± 0.54 | 0.907 |
| Individual pig weight at weaning, kg | 6.54 ± 0.13 | 6.67 ± 0.12 | 0.853 |
| Litter weight after cross-foster, kg | 20.02 ± 0.50 | 19.69 ± 0.57 | 0.211 |
| Litter weight at weaning, kg | 61.88 ± 1.88 | 61.43 ± 1.69 | 0.842 |
| ADG, g/day | 212.09 ± 5.80 | 223.31 ± 4.88 | 0.435 |

ADFI, average daily feed in take during lactation; ADG, average daily gain. A P < 0.05 indicates a significant difference among treatments.
TABLE 4 | Effects of dietary MGDG supplementation during late gestation and lactation on sow back fat thickness and estrus interval.

| Parameter                        | Control | MGDG | P-value |
|----------------------------------|---------|------|---------|
| n                                | 50      | 50   |         |
| Sow back fat                     |         |      |         |
| Back fat at farrowing             | 18.33 ± 1.23 | 18.50 ± 0.72 | 0.905 |
| Back fat at weaning              | 14.92 ± 0.53 | 16.77 ± 0.42 | 0.023 |
| Back fat loss during lactation   | 3.41 ± 0.43 | 2.16 ± 0.29 | 0.029 |
| Estrus rate within 7 days after weaning (%) | 91.49 | 91.30 | 0.795 |

A P < 0.05 indicates the existence of a significant difference among treatments.

“a,b” means values within a row with different letters superscripts means significantly different (P < 0.05).

TABLE 5 | Effects of dietary MGDG supplementation during late gestation and lactation on sow colostrum and milk composition.

| Parameter | Control | MGDG | P-value |
|-----------|---------|------|---------|
| Colostrum (%) |         |      |         |
| Non-fat-solids | 20.90 ± 0.46 | 19.26 ± 0.92 | 0.109 |
| Protein   | 11.33 ± 0.23 | 10.27 ± 0.62 | 0.102 |
| Fat       | 4.46 ± 0.40 | 5.42 ± 0.32 | 0.087 |
| Lactose   | 7.89 ± 0.19 | 7.23 ± 0.37 | 0.115 |
| Milk (%)  |         |      |         |
| Non-fat-solids | 10.35 ± 0.15 | 10.63 ± 0.12 | 0.147 |
| Protein   | 3.80 ± 0.06 | 3.92 ± 0.04 | 0.123 |
| Fat       | 6.93 ± 0.23 | 7.09 ± 0.32 | 0.696 |
| Lactose   | 5.85 ± 0.12 | 5.91 ± 0.07 | 0.052 |

A P < 0.05 indicates the existence of a significant difference among treatments.

Immunoglobulin Concentrations
The effects of dietary MGDG supplementation during late gestation and lactation on the immunoglobulin concentrations in sow colostrum and milk are shown in Table 6. No significant treatment differences were observed in terms of IgG, IgM, and IgA levels in colostrum and milk (P > 0.05; Table 6).

Cytokine Concentrations
The effects of dietary MGDG supplementation during late gestation and lactation on the cytokine concentrations in sow colostrum, milk, and plasma are shown in Table 7. Compared with the sows fed the control diet, those fed the MGDG-supplemented diet had a lower TNF-α concentration in their colostrum (P < 0.05; Table 7). During the lactation period, lower cytokine concentrations in sow plasma were observed on L10 (IL-8), L14 (IL-18), and L21 (IL-18) (P < 0.05).

Blood Parameter Concentrations
The effects of dietary MGDG supplementation during late gestation and lactation on blood parameters in the plasma of sows are shown in Table 8. On L14, the GLU levels in plasma were higher in MGDG-fed sows than in sows in the control group. On the day of weaning, the TCHO content in plasma was lower in the MGDG group than in the control group (P < 0.05; Table 8). The PUN, HDL-C, LDL-C, and TG levels were not affected by MGDG supplementation (P > 0.05).

DISCUSSION
In this study, supplementation with MGDG in a sow diet reduced back fat loss during the lactation period. To date, the effects of backfat on sow reproductive performance are still
Inconsistent. Some contend that backfat is not a reliable predictor of subsequent sow reproductive performance (26), but other scientists argue that there is an optimal range of backfat (15–16 mm or even at least 20 mm) for maintaining subsequent reproduction (23, 24). Increasing dietary energy levels is an effective way to reduce back fat thickness. Another possible reason is that MGDG acts as a critical component in the diet, which has been found to improve the absorption and utilization of essential nutrients such as fat, protein, and carbohydrates (27). Sows fed MGDG-supplemented diet might have used less stored body energy than sows fed the control diet. The MGDG diet contained a higher level of net energy (calculated value), which could directly alleviate the loss of back fat thickness. Further research is still required to verify this hypothesis.

Table 8: Effects of dietary MGDG supplementation during late gestation and lactation on sow plasma constituent concentrations.

| Item                  | Control | MGDG | P-value |
|-----------------------|---------|------|---------|
| n                     | 10      | 10   |         |
| Day 8 of gestation (mmol/L) |        |      |         |
| GLU                   | 4.77 ± 0.21 | 4.43 ± 0.24 | 0.312 |
| TG                    | 1.87 ± 0.29 | 1.69 ± 0.11 | 0.558 |
| TCHO                  | 7.26 ± 0.52 | 8.43 ± 1.03 | 0.323 |
| HDL-C                 | 0.77 ± 0.12 | 0.80 ± 0.07 | 0.794 |
| LDL-C                 | 1.11 ± 0.07 | 0.92 ± 0.09 | 0.104 |
| PUN                   | 7.96 ± 0.33 | 7.71 ± 0.51 | 0.684 |
| Day of farrowing (mmol/L) |        |      |         |
| GLU                   | 4.80 ± 0.33 | 5.40 ± 0.32 | 0.207 |
| TG                    | 1.87 ± 0.41 | 1.81 ± 0.11 | 0.772 |
| TCHO                  | 6.07 ± 0.41 | 5.23 ± 0.81 | 0.366 |
| HDL-C                 | 0.86 ± 0.07 | 0.61 ± 0.10 | 0.054 |
| LDL-C                 | 1.30 ± 0.10 | 1.11 ± 0.15 | 0.340 |
| PUN                   | 7.34 ± 0.66 | 7.89 ± 0.41 | 0.444 |
| Day 14 of lactation (mmol/L) |        |      |         |
| GLU                   | 4.81± ± 0.32 | 5.03± ± 0.21 | 0.010 |
| TG                    | 1.71 ± 0.14 | 1.52 ± 0.11 | 0.306 |
| TCHO                  | 11.59 ± 0.77 | 10.29 ± 1.23 | 0.388 |
| HDL-C                 | 1.60 ± 0.36 | 1.07 ± 0.05 | 0.179 |
| LDL-C                 | 1.99 ± 0.65 | 1.04 ± 0.08 | 0.164 |
| PUN                   | 11.48 ± 0.37 | 11.13 ± 0.54 | 0.599 |
| Day of weaning (mmol/L) |         |      |         |
| GLU                   | 5.88 ± 0.35 | 5.15 ± 0.36 | 0.162 |
| TG                    | 1.77 ± 0.20 | 1.45 ± 0.21 | 0.288 |
| TCHO                  | 12.15± ± 1.08 | 9.05§ ± 0.58 | 0.021 |
| HDL-C                 | 1.41 ± 0.04 | 1.13 ± 0.08 | 0.111 |
| LDL-C                 | 1.66 ± 0.15 | 1.39 ± 0.12 | 0.127 |
| PUN                   | 10.21 ± 0.61 | 9.14 ± 0.83 | 0.176 |

GLU, glucose; TG, triglyceride; TCHO, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; PUN, plasma urea nitrogen. A P-threshold <0.05 indicates the existence of significant difference among treatments. 

Data signify values within a row with different letters superscripts means significantly different (P < 0.05).
production during lactation. Therefore, MGDG supplementation might have enhanced the digestion and absorption of lipids, thus increasing the energy supply to lactating sows in this study.

Collectively, this study found that dietary MGDG supplementation during late gestation and lactation improves sow body condition and alleviates inflammation. Further research is warranted to examine whether dietary MGDGs regulate the inflammation of sows through the modification of intestinal microbes.

**DATA AVAILABILITY STATEMENT**

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

**ETHICS STATEMENT**

The animal study was reviewed and approved by South China Agricultural University Animal Care and Use Committee.

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Written informed consent was obtained from the owners for the participation of their animals in this study.

**AUTHOR CONTRIBUTIONS**

HS and WC carried out this experiment collected data and wrote the manuscript. WG and SZ designed the research and gave guidance on writing paper. SZ, FC, MR, and WG reviewed the manuscript. HS, WC, and FY helped to prepare the experiment. All authors read and approved the final manuscript.

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