

Effects of Dietary Medium-Chain Triglyceride Supplementation on Reproductive Performance, Serum Biochemical Indices, and Colostrum Composition in Sows: Postprint

Authors: Wenfei Zhang, Zhang Hongju, Guan Wutai, Chen Jun, Xufang Luo, Chen Fang, Deng Yuelin

Date: 2017-10-11T00:00:00+00:00

Abstract

This experiment aimed to investigate the effects of adding medium-chain triglycerides (MCT) to sow diets during late gestation and lactation on sow reproductive performance, serum biochemical indices, and colostrum composition. One hundred and twenty purebred Large White pregnant sows (parity 3-5) were selected and divided into 3 groups according to the principle of balanced distribution of expected farrowing date, parity, body condition, and historical reproductive performance, with 40 replicates per group and 1 sow per replicate. The control group was fed a basal diet (containing 3.17% soybean oil), the oil group had 0.6% pure oil MCT replace 0.6% soybean oil in the basal diet (containing 2.57% soybean oil), and the powder group had 0.5% microencapsulated powder MCT added to the basal diet. The experiment started from day 85 of gestation and ended at piglet weaning. The results showed: 1) Compared with the control group, the farrowing duration of sows in the oil group and powder group decreased by 17.58% ($P < 0.05$) and 9.21% ($P > 0.05$), respectively; the average daily feed intake during lactation increased by 5.92% and 10.07% ($P > 0.05$), respectively; the estrus rate within 7 days post-weaning increased by 6.52% and 4.25% ($P > 0.05$), respectively; dietary MCT supplementation had no significant effect on other reproductive performance indicators of sows ($P > 0.05$). 2) Dietary MCT supplementation had no significant effect on sow serum biochemical indices ($P > 0.05$). 3) Compared with the control group, the colostrum fat content of sows in the oil group and powder group increased by 18.09% and 19.09% ($P > 0.05$), respectively; dietary MCT supplementation had no significant effect on sow colostrum composition ($P > 0.10$). In conclusion, adding MCT to sow diets during late gestation and lactation failed to improve sow production performance, serum biochemical indices, and colostrum composition, but adding

oil-form MCT could significantly shorten sow farrowing duration.

Full Text

Effects of Dietary Supplementation of Medium-Chain Triglycerides on Reproductive Performance, Serum Biochemical Indices, and Colostrum Composition of Sows

ZHANG Wenfei^{1,2}, ZHANG Hongju^{1,2}, GUAN Wutai^{1,2*}, CHEN Jun^{1,2}, LUO Xufang¹, CHEN Fang¹, DENG Yuelin^{1} (1. College of Animal Science, South China Agricultural University, Guangzhou 510642, China; 2. SCAU-Unioil Feeding Oil & Fat Research Centre, College of Animal Science, South China Agricultural University, Guangzhou 510642, China)

Abstract: This experiment was conducted to investigate the effects of dietary supplementation of medium-chain triglyceride (MCT) on reproductive performance, serum biochemical indices, and colostrum composition of sows during late gestation and lactation. A total of 120 purebred Yorkshire sows (parity 3–5) were allocated to three groups according to principles of balanced distribution based on predicted farrowing date, parity, body condition, and historical reproductive performance. Each group contained 40 replicates with one sow per replicate. The control group was fed a basal diet (containing 3.17% soybean oil), the oil group was fed a diet in which 0.6% pure oil-type MCT replaced 0.6% soybean oil (containing 2.57% soybean oil), and the powder group was fed the basal diet supplemented with 0.5% microencapsulated powder-type MCT. The trial was conducted from day 85 of gestation until piglet weaning. The results showed that: (1) Compared with the control group, the oil and powder groups exhibited decreased labor duration by 17.58% ($P < 0.05$) and 9.21% ($P > 0.05$), respectively; increased average daily feed intake during lactation by 5.92% and 10.07% ($P > 0.05$), respectively; and increased 7-day post-weaning estrus rate by 6.52% and 4.25% ($P > 0.05$), respectively. Dietary MCT supplementation had no significant effects on other reproductive performance indices ($P > 0.05$). (2) Dietary MCT supplementation had no significant effects on serum biochemical indices of sows ($P > 0.05$). (3) Compared with the control group, colostrum fat content in the oil and powder groups increased by 18.09% and 19.09% ($P > 0.05$), respectively. Dietary MCT supplementation had no significant effects on colostrum composition ($P > 0.10$). In conclusion, dietary supplementation of MCT during late gestation and lactation did not improve sow productivity performance, serum biochemical indices, or colostrum composition, but oil-type MCT supplementation significantly shortened sow labor duration.

Keywords: medium-chain triglyceride; sows; reproductive performance; serum biochemical indices; colostrum composition

Fats are important sources of energy and essential fatty acids for animals, providing high caloric value and facilitating absorption of fat-soluble vitamins, thus

playing a crucial role in sow nutrition and diets [1-2]. Supplementing appropriate levels of fat in sow diets during late gestation and lactation can improve litter performance. Adding fat to lactation diets can increase feed intake (or energy intake) and essential fatty acid intake, enhance milk yield and milk fat percentage, improve lactation performance, and reduce body weight and backfat loss during lactation, thereby preparing sows for the subsequent reproductive cycle [3]. Supplementing high-energy fats during late gestation and lactation can meet sow energy requirements, improve pre-weaning survival rates and birth weights of newborn piglets [4-5], and increase weaning weights [6]. Lauridsen et al. [7] demonstrated that adding different sources and levels of fat to sow lactation diets positively affected offspring production by influencing milk fat percentage and energy content, findings supported by Jackson et al. [8] and Averette et al. [9]. Previous work by Lv et al. [10] from our laboratory also indicated that fatty acids play important roles in milk fat synthesis and transport in sow mammary cells. Therefore, adding fats to sow diets during late gestation is common practice in modern pig farms. However, excessive supplementation of high-energy fats can increase peripartum stress, exacerbate insulin resistance [11], induce gestational hyperglycemia, and cause metabolic disorders [12].

Medium-chain triglycerides (MCT) are fatty acid triglycerides containing 8-12 carbon atoms, characterized by low caloric value, short carbon chains, rapid digestion and absorption, and fast oxidative metabolism in vivo, enabling rapid energy supply for sows [13-19]. Gatlin et al. [20] reported that adding 10% MCT to sow diets from day 90 of gestation to day 15 of lactation significantly increased average daily gain and weaning weight of piglets compared with the control group. Azain et al. [21] found that adding 10% MCT to sow diets from day 91 of gestation to day 7 postpartum improved survival rate of piglets weighing less than 900 g by 36% compared with a starch-fed control group. Nevertheless, limited research has been reported on the effects of dietary MCT supplementation on sow reproductive performance, serum biochemical indices, and colostrum composition. Therefore, this experiment aimed to investigate these effects and provide theoretical basis and practical reference for MCT application in pig production.

1.1 Experimental Materials

The pure oil-type MCT used in this experiment was commercially named caprylic/capric triglyceride (purity >99%, containing 56% caprylic glyceride and 43% capric glyceride). The water-soluble microencapsulated powder-type MCT was commercially named “Zhi Zhuang Su (Fat Fortifier)” (crude fat 50.0%, crude protein 0.5%, total carbohydrates 38.0%, moisture 4.0%).

1.2 Experimental Design and Management

A total of 120 purebred Yorkshire gestating sows (parity 3-5) were selected and divided into three groups according to principles of balanced distribution based

on predicted farrowing date, parity, body condition, and historical reproductive performance. Each group comprised 40 replicates with one sow per replicate. The three groups were: control group (fed basal diet containing 3.17% soybean oil), oil group (fed diet where 0.6% pure oil-type MCT replaced 0.6% soybean oil, containing 2.57% soybean oil + 0.6% pure oil-type MCT), and powder group (fed basal diet supplemented with 0.5% microencapsulated powder-type MCT, containing 3.17% soybean oil + 0.5% microencapsulated powder-type MCT). The trial was conducted from day 85 of gestation until piglet weaning.

The experiment was carried out at a breeding farm under Guangdong Wens Foodstuff Group Co., Ltd. Sows during late gestation were housed individually in farrowing crates and transferred to farrowing houses two days before expected parturition. During late gestation, sows were fed 2.5–3.4 kg/d diet according to body condition, divided into two meals (08:00 and 15:30). No feed was provided on the day of parturition. On day 1 postpartum, 2.0 kg was fed, then increased gradually by 0.5 kg/d until ad libitum feeding on day 10 of lactation. Sows had free access to water throughout the experimental period. To standardize litter size, litters were adjusted to 10–12 piglets within 12 h postpartum, with adjustments made within the same group.

1.3 Experimental Diets

The basal diet was a corn-soybean meal type diet with nutritional indices meeting the requirements for late gestation and lactation sows according to NRC (1998). The composition and nutrient levels of the basal diet are presented in Table 1.

Table 1 Composition and nutrient levels of the basal diet (air-dry basis), %

Note: (1) The premix provided the following per kg of diet: VA 9,200 IU, VD 1,300 IU, VE 20 mg, VK3 2 mg, VB1 2 mg, VB2 0.03 mg, VB6 2 mg, nicotinic acid 29 mg, pantothenic acid 6 mg, folic acid 0.1 mg, Se 0.1 mg, Cu 32 mg, Fe 30 mg, Zn 20 mg, Mn 10 mg, I 0.2 mg. (2) Nutrient levels were calculated values.

1.4 Sample Collection

1.4.1 Milk Samples At parturition, 15 sows were randomly selected from each group. After warm compresses were applied to the udder, colostrum was collected from anterior, middle, and posterior teats (10 mL per sow) and stored at -20°C until analysis.

1.4.2 Blood Samples On day 14 of lactation at 09:00, 5 mL of blood was collected from the ear vein of 6 randomly selected sows from each group that had provided colostrum samples (fasted state). After standing at room temperature for 1 h, serum was separated by centrifugation at 3,000 r/min for 15 min, aliquoted into EP tubes, and stored at -20°C.

1.5 Measurement Indicators

1.5.1 Reproductive Performance At parturition, labor duration, total number of piglets born, number of live-born piglets, number of stillbirths, number of mummified fetuses, number of weak piglets (weight <800 g), number of live piglets, litter weight at birth, and individual piglet birth weight were recorded. At weaning on day 21, number of weaned piglets, weaning litter weight, and individual weaning weight were recorded, and weaning survival rate was calculated. Additionally, average daily gain and average daily feed intake of sows during lactation, as well as estrus rates by day 5 and day 7 post-weaning, were calculated.

1.5.2 Serum Biochemical Indices Assay kits for serum glucose, total cholesterol, total protein, and urea nitrogen were purchased from Nanjing Jiancheng Bioengineering Institute (catalog numbers: F006, A111-2, A045-2, C013-2), and procedures were performed according to manufacturer instructions.

1.5.3 Colostrum Composition Analysis Colostrum components including milk fat, lactose, milk protein, solids-not-fat, and crude ash were determined using a UL40AC rapid milk composition analyzer (Hangzhou Zhejiang University Youchuang Technology Co., Ltd.).

1.6 Statistical Analysis

Experimental data were analyzed using SPSS 18.0 software for one-way ANOVA with Duncan's multiple comparison test. Sow return-to-estrus rate and piglet survival rate were analyzed using chi-square test. $P < 0.05$ indicated significant difference. Results are expressed as means \pm SE.

2.1 Effects of Dietary MCT Supplementation on Sow Reproductive Performance

As shown in Table 2, dietary MCT supplementation affected sow labor duration. Compared with the control group, labor duration in the oil group was shortened by 17.58% ($P < 0.05$), while the powder group showed a 9.21% reduction that did not reach significance ($P > 0.05$). The oil and powder groups exhibited increased average daily feed intake by 5.92% and 10.07% ($P > 0.05$), respectively, and increased 7-day estrus rates by 6.52% and 4.25% ($P > 0.05$), respectively. No significant effects were observed on other reproductive performance indices ($P > 0.05$).

Table 2 Effects of dietary supplementation of MCT on reproductive performance of sows

Note: In the same row, values with different small letter superscripts indicate significant difference ($P < 0.05$), while values with the same or no letter superscripts indicate no significant difference ($P > 0.05$). The same applies below.

2.2 Effects of Dietary MCT Supplementation on Sow Serum Biochemical Indices

As shown in Table 3 , dietary MCT supplementation had no significant effects on sow serum biochemical indices ($P>0.05$).

Table 3 Effects of dietary supplementation of MCT on serum biochemical indices of sows

2.3 Effects of Dietary MCT Supplementation on Sow Colostrum Composition

As shown in Table 4 , dietary MCT supplementation had no significant effects on sow colostrum composition ($P>0.05$). However, compared with the control group, milk fat content in colostrum increased by 1.27% and 1.34% ($P>0.05$) in the oil and powder groups, respectively.

Table 4 Effects of dietary supplementation of MCT on colostrum composition of sows

3.1 Effects of Dietary MCT Supplementation on Sow Reproductive Performance

Feed intake is crucial for lactating sows. Low feed intake during lactation not only reduces milk yield and affects piglet growth and development [22-23], but also causes excessive body fat loss, prolonging the weaning-to-estrus interval [24]. Li et al. [25] reported that feeding 30 third-parity sows diets without fat supplementation or with 2% soybean oil or 2% fat powder showed no significant effects of different fat sources on average daily feed intake of lactating sows, consistent with Shurson et al. [6]. Jin et al. [26] reported that feeding sows diets without fat or supplemented with palm oil, mixed oil, or soybean oil from day 90 of gestation to day 17 of lactation (3% fat during gestation and 4% during lactation) significantly reduced average daily feed intake during lactation, though total digestible energy intake did not differ among groups. Generally, adding fat to sow diets reduces lactation feed intake due to increased energy density but elevates energy intake. Under similar dietary energy levels, fat supplementation does not affect lactation feed intake [3]. In this experiment, compared with the control group, average daily feed intake during lactation increased by 5.92% in the oil group and 10.07% in the powder group, but differences were not significant, consistent with previous results.

Providing adequate energy to sows can shorten labor duration, reduce incidence of asphyxiation-related deaths during farrowing, supply sufficient energy to newborn piglets, and improve piglet survival rates [27-30]. Energy intake during lactation is also an important factor affecting post-weaning estrus. Zhou et al. [31] divided 54 gilts into six groups fed diets with three energy levels (medium energy level based on NRC (1998) recommendations, with low and high levels reduced or increased by 12.5%) and two energy sources (starch vs. fat), report-

ing that estrus rate increased with energy level and that backfat thickness and body fat content were positively correlated with estrus rate. In this experiment, compared with the control group, 5-day and 7-day estrus rates increased by 3.15% and 6.52% in the oil group and by 4.05% and 4.25% in the powder group, respectively, though differences were not significant.

Guan Wutai [3] reviewed research findings from the past two decades with relatively large sample sizes (20 replicates per group) and concluded that adding fat to sow diets during late gestation had no significant effects on litter performance indices such as total number of piglets born, number of live-born piglets, average individual birth weight, and litter birth weight, but significantly improved litter weaning weight, average individual weaning weight, number of weaned piglets, average daily gain, and litter weight gain.

Van Dijk et al. [32] demonstrated that adding MCT to sow diets during late gestation could improve metabolic disorders and stabilize blood insulin levels, providing rapid energy to ensure adequate physical strength during parturition, thereby shortening labor and reducing stillbirths. Dunshea et al. [33] showed that dietary triglycerides could be directly utilized by mammary tissue, increasing medium-chain triglyceride content in milk fat and providing more energy to piglets, thus improving survival rates. Chen et al. [34] reported that administering 4 mL/head MCT to piglets at 12 and 36 h after birth increased average daily gain by 14% at weaning. Zhu et al. [35] found that feeding medium-chain fatty acids to newborn piglets increased survival rate from 71.40% to 84.04%. The results of this experiment are consistent with these findings, showing increased number of live-born piglets and litter birth weight in treatment groups compared with the control group, though differences were not significant.

Sow labor duration not only affects the number of live-born piglets but also influences piglet postnatal survival rates and sow longevity. For sows, prolonged labor leads to postpartum hemorrhage and infection, extending the weaning-to-estrus interval and increasing the culling rate in subsequent parities. For piglets, prolonged passage through the birth canal increases risk of asphyxiation and death [36]. Nutritional factors causing prolonged labor include: (1) insufficient glucose utilization and energy deficiency during late gestation, leading to weak uterine contractions; (2) excessive backfat deposition during late gestation, narrowing the birth canal due to fat accumulation and causing dystocia; and (3) occupation of intestinal space by hard fecal masses, compressing the birth canal and hindering piglet passage, while constipation-induced pain promotes opioid peptide secretion, which inhibits oxytocin secretion and reduces uterine contractility [37]. In this experiment, oil-type MCT supplementation significantly shortened sow labor duration by 17.58% compared with the control group. This may be attributed to the rapid energy supply from MCT meeting the substantial energy demands during parturition, and MCT's ability to improve insulin resistance and reduce backfat deposition during late gestation, thereby decreasing birth canal narrowing caused by excessive fat.

3.3 Effects of Dietary MCT Supplementation on Sow Serum Biochemical Indices

Glucose is the primary energy source for maintenance and growth in most animals, regulating appetite and feed intake through neuroregulation of cell activity. Studies on lactating sows have also found that feed intake is associated with serum insulin and glucose concentrations, with low serum glucose increasing sow feed intake [38]. Serum urea nitrogen accurately reflects protein metabolism and dietary amino acid balance, with lower concentrations indicating higher nitrogen utilization efficiency. In this study, dietary MCT supplementation did not affect sow serum glucose concentration. Serum cholesterol is a product of incomplete fatty acid oxidation. McWhinney et al. [39] administered coconut oil (primarily containing MCT) to newborn piglets and found no significant change in serum total cholesterol concentration. Similarly, this experiment showed no effect of dietary MCT supplementation on sow serum total cholesterol concentration.

3.4 Effects of Dietary MCT Supplementation on Sow Colostrum Composition

Sow colostrum nutritional composition largely determines piglet growth performance during lactation and serves as an important indicator of sow nutritional status [40]. Milk fat is a crucial component of milk, playing important roles in energy supply and growth regulation of piglets, with its precursors derived from chylomicron triglycerides in blood. Lactose and milk protein concentrations in sow colostrum are generally not affected by dietary changes, whereas milk fat concentration is highly susceptible to dietary influence [8,41-42]. Dietary triglycerides can be used for both lipid synthesis in the body and milk fat synthesis. Dietary MCT supplementation in sows can be directly absorbed by the intestine with minimal use for lipid synthesis, thereby increasing milk fat concentration. This experiment confirmed this concept, showing that dietary MCT supplementation increased sow milk fat concentration by 1.27% in the oil group and 1.34% in the powder group compared with the control group, though differences were not significant. While limited research exists on sow milk, dairy cow studies have shown that supplementing diets with 200 and 400 g/t caprylic/capric triglycerides had no significant effects on milk yield, blood physiological and biochemical indices, nutrient apparent digestibility, or energy and nitrogen metabolism, but significantly increased milk fat concentration. Both porcine and bovine studies indicate that dietary MCT supplementation during lactation can increase milk fat concentration. The non-significant effects of dietary MCT supplementation on sow colostrum composition in this experiment may be attributed to the relatively low supplementation level.

Conclusion

Dietary supplementation of MCT during late gestation and lactation had no significant effects on sow average daily feed intake, serum biochemical indices,

colostrum composition, or nursing piglet growth performance, but oil-type MCT supplementation significantly shortened sow labor duration.

References

- [1] MCDONALD P. Animal nutrition[M]. Essex: Pearson Education, 2010: 37-38.
- [2] ROSERO D S, VAN HEUGTEN E, ODLE J, et al. Response of the modern lactating sow and progeny to source and level of supplemental dietary fat during high ambient temperatures[J]. *Journal of Animal Science*, 2012, 90(8): 2609-2619.
- [3] GUAN Wutai. Research progress on the application of oils in sow diets[J]. *Acta Zoonutritional Sinica*, 2014, 26(10): 3078-3088.
- [4] TILTON S L, MILLER P S, LEWIS A J, et al. Addition of fat to the diets of lactating sows: I. Effects on milk production and composition and carcass composition of the litter at weaning[J]. *Journal of Animal Science*, 1999, 77(9): 2491-2500.
- [5] CHWEN L T, FOO H L, THANH N T, et al. Growth performance, plasma fatty acids, villous height and crypt depth of preweaning piglets fed with medium chain triacylglycerol[J]. *Asian-Australasian Journal of Animal Sciences*, 2013, 26(5): 700-704.
- [6] SHURSON G C, HOGBERG M G, DEFEVER N, et al. Effects of adding fat to the sow lactation diet on lactation and rebreeding performance[J]. *Journal of Animal Science*, 1986, 62(3): 672-680.
- [7] LAURIDSEN C, DANIELSEN V. Lactational dietary fat levels and sources influence milk composition and performance of their progeny[J]. *Livestock Production Science*, 2004, 91(1/2): 95-105.
- [8] JACKSON J R, HURLEY W L, EASTER R A, et al. Effects of induced or delayed parturition and supplemental dietary fat on colostrum and milk composition in sows[J]. *Journal of Animal Science*, 1995, 73(7): 1906-1913.
- [9] AVERETTE L A, ODLE J, MONACO M H, et al. Dietary fat during pregnancy and lactation increases milk fat and insulin-like growth factor I concentrations and improves neonatal growth rates in swine[J]. *The Journal of Nutrition*, 1999, 129(12): 2123-2129.
- [10] LV Y T, GUAN W T, QIAO H Z, et al. Veterinary medicine and omics (Veterinomics): metabolic transition of milk triacylglycerol synthesis in sows from late pregnancy to lactation[J]. *OMICS: A Journal of Integrative Biology*, 2015, 19(10): 602-616.
- [11] GREENBERG A S, OBIN M S. Obesity and the role of adipose tissue in inflammation and metabolism[J]. *The American Journal of Clinical Nutrition*, 2006, 83(2): 461S-465S.
- [12] PÈRE M C, ETIENNE M, DOURMAD J Y. Adaptations of glucose metabolism in multiparous sows: effects of pregnancy and feeding level[J]. *Journal of Animal Science*, 2000, 78(11): 2933-2941.
- [13] BACH A C, BABAYAN V K. Medium-chain triglycerides: an update[J]. *The American Journal of Clinical Nutrition*, 1982, 36(5): 950-962.
- [14] HE Jian. Metabolism and application of medium-chain triglycerides in animals[J]. *China Oils and Fats*, 2004, 29(1): 14-18.
- [15] YANG Jintang, HUANG Kehe, WANG Jianlin, et al. Research progress on application of medium-chain fatty acids in animal husbandry[J]. *Animal Husbandry and Veterinary Medicine*, 2009, 41(5): 100-105.
- [16] ECKEL R H, HANSON A S, CHEN A Y, et al. Dietary substitution of medium-chain triglycerides improves insulin-mediated glucose metabolism NIDDM subjects[J]. *Diabetes*, 1992, 41(5): 641-647.
- [17] RAMÍREZ M, AMATE L, GIL A. Absorption and distribution of

dietary fatty acids from different sources[J]. *Early Human Development*, 2001, 65(Suppl.2): S95-S101. [18] DE GREEF A, BIKKER P, SMIT-HEINSBROEK A, et al. Increased fat and polyunsaturated fatty acid content in sow gestation diet has no effect on gene expression in progeny during the first 7 days of life[J]. *Journal of Animal Physiology and Animal Nutrition*, 2016, 100(1): 127-135. [19] CHANG P S, ZUCKERMANN A M E, WILLIAMS S, et al. Seizure control by derivatives of medium chain fatty acids associated with the ketogenic diet show novel branching-point structure enhanced potency[J]. *Journal Pharmacology Experimental Therapeutics*, 2015, 352(1): 43-52. [20] GATLIN L A, ODLE J, SOEDE J, et al. Dietary medium- or long-chain triglycerides improve body condition of lean-genotype sows and increase suckling pig growth[J]. *Journal of Animal Science*, 2002, 80(1): 38-44. [21] AZAIN M J. Effects of adding medium-chain triglycerides to sow diets during late gestation and early lactation on litter performance[J]. *Journal of Animal Science*, 1993, 71(11): 3011-3019. [22] SMITH D M. The yield and energy content of milk and the energetic efficiency of sows on different levels of nutrition during gestation and lactation[J]. *New Zealand Journal of Agricultural Research*, 1960, 3(5): 745-763. [23] CI L, LIU Z Q, GUAN W T, et al. The influence of maternal dietary fat on the fatty acid composition and lipid metabolism in the subcutaneous fat of progeny pigs[J]. *Meat Science*, 2015, 108: 82-87. [24] KOKETSU Y, DIAL G D, PETTIGREW J E, et al. Characterization of feed intake patterns during lactation in commercial swine herds[J]. *Journal of Animal Science*, 1996, 74(6): 1202-1210. [25] LI Bo, CHEN Daiwen, LEI Xiaoya, et al. Effects of different fat sources on reproductive performance and nutrient digestibility of lactating sows[J]. *Chinese Journal of Animal Science*, 2011, 47(9): 31-35. [26] JIN Chao. Effects of adding different types of oils to diets on performance and milk composition of multiparous sows[D]. Master's Thesis. Ya'an: Sichuan Agricultural University, 2011: 27-29. [27] YU Guiyang. Study on effects of energy and protein levels on reproductive performance of Landrace-Yorkshire crossbred sows[D]. Master's Thesis. Changsha: Hunan Agricultural University, 2003: 23-28. [28] ZHANG Jinzhi. Study on effects of dietary energy structure on reproductive and lactation performance of sows[D]. Doctoral Dissertation. Hangzhou: Zhejiang University, 2009: 61-69. [29] LI Y, ZHANG H, YANG L, et al. Effect of medium-chain triglycerides on growth performance, nutrient digestibility, plasma metabolites and antioxidant capacity in weanling pigs[J]. *Animal Nutrition*, 2015, 1(1): 12-18. [30] LIU Y L. Fatty acids, inflammation and intestinal health in pigs[J]. *Journal of Animal Science and Biotechnology*, 2015, 6: 41. [31] ZHOU Ping, WU De, ZHOU Dongsheng, et al. Effects of energy level and source on body composition, age at puberty, and estrus expression of replacement gilts[J]. *Acta Zoonutritional Sinica*, 2009, 21(2): 123-129. [32] VAN DIJK A J, VAN RENS B T T M, VAN DER LENDE T, et al. Factors affecting duration of the expulsive stage of parturition and piglet birth intervals in sows with uncomplicated, spontaneous farrowings[J]. *Theriogenology*, 2005, 64(7): 1573-1590. [33] DUNSHEA F R, BELL A W, TRIGG T E. Relations between plasma non-esterified fatty acid metabolism and body fat mobilization in primiparous lactating goats[J]. *British Journal of Nutrition*, 1989, 62(1): 51-61. [34] CHEN Zanmou. Study on

the feeding effect of adding medium-chain fat preparation to suckling piglets[J]. Journal of Domestic Animal Ecology, 1999, 20(1): 4-6. [35] ZHU Chenglin, SUN Jiapeng. Effect of medium-chain fatty acids on survival rate and weight gain of newborn piglets[J]. Xinjiang Animal Husbandry, 2000(Suppl.1): 11-14. [36] VAN DER LENDE T, KNOL E F, LEENHOUWERS J I. Prenatal development as a predisposing factor perinatal losses pigs[J]. Reproduction (Cambridge, England) Supplement, 2001, 58: 247-261. [37] COWART R P. Parturition and dystocia in swine[M]//YOUNGQUIST R S, THRELFALL W R. Current therapy in large animal theriogenology. 2nd ed. St. Louis, MI, USA: Saunders, 2007: 778-784. [38] MOSNIER E, LE FLOC' H N, ETIENNE M, et al. Reduced feed intake of lactating primiparous sows is associated with increased insulin resistance during the peripartum period and is not modified through supplementation dietary tryptophan[J]. Journal Animal Science, 2014, 88(2): 612-625. [39] MCWHINNEY V J, POND W G, MERSMANAN H J. Ontogeny and dietary modulation of 3-Hydroxy-3-Methylglutaryl-CoA reductase activities in neonatal pigs[J]. Journal of Animal Science, 1996, 74(9): 2203-2210. [40] NOBLET J, DOURMAD J Y, ETIENNE M. Energy utilization in pregnant and lactating sows: modeling of energy requirements[J]. Journal of Animal Science, 1990, 68(2): 562-572. [41] KROGH U, BRUUN T S, AMDI C, et al. Colostrum production in sows fed different sources of fiber and fat during late gestation[J]. Canadian Journal of Animal Science, 2015, 95(2): 211-223. [42] VICENTE J G, ISABEL B, CORDERO G, et al. Fatty acid profile of the sow diet alters fat metabolism and fatty acid composition in weanling pigs[J]. Animal Feed Science and Technology, 2013, 181(1): 45-53.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv – Machine translation. Verify with original.