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Probiotics or synbiotics addition in Bama Mini-pigs' diets improves growth performance, carcass traits, and meat quality by altering plasma metabolites and related gene expression of offspring pigs

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Abstract

The present study evaluated the effects of maternal probiotics or synbiotics addition on growth performance, carcass traits, meat quality, plasma metabolites, and related gene expression of their offspring pigs. A total of 64 Bama mini-pigs were used and randomly divided into the control, antibiotic, probiotics, or synbiotics groups, and fed experimental diets during pregnancy and lactation. After weaning, two piglets per litter and eight piglets per group were selected and fed a basal diet. At 65-, 95-, and 125-day-old, eight pigs per group were selected for analysis. The results showed that probiotics addition increased the ADFI of pigs during the 66–95 day-old and the backfat thickness at 65- and 125-day-old, whereas synbiotics addition increased backfat thickness and decreased muscle percentage and loin-eye area at 125-day-old. In meat quality, probiotics or synbiotics addition increased cooking yield, pH_{45min}, and meat color, while decreased drip loss and shear force at different stages. However, maternal antibiotic addition showed an increased shear force at 125-day-old. Dietary probiotics or synbiotics addition in sow diets increased several amino acids (AA) contents in the plasma and *longissimus thoracis* (LT) muscle, including total AA (TAA), His, Met, Asp, Arg, and Leu, while decreased Gly, Pro, Ile, α -AAA, α -ABA, β -Ala, and γ -ABA at different stages. In the LT muscle fatty acid (FA) analysis, the contents of saturated FA (SFA; including C16:0, C17:0, and C20:0) and C18:1n9t were decreased, and the contents of C18:2n6c, MUFA (C16:1 and C20:1) and UFA were increased in the probiotics group, while the contents of SFA (C10:0, C12:0, and C14:0 at 65-day-old)

were increased and the contents of C20:1 and C18:1n9t were decreased in the synbiotics group. Plasma biochemical analysis revealed that maternal probiotics or synbiotics addition decreased plasma AMM, UN, and GLU, while synbiotics addition increased plasma ALT, HDL-C, and TC at different stages. Moreover, maternal probiotics or synbiotics regulated muscle fiber-type, myogenic regulatory, and lipid metabolism-related gene expressions of offspring pigs. In conclusion, maternal probiotics or synbiotics addition, as a nutritional intervention strategy, improved feed intake and meat quality by altering the body's metabolism of offspring pigs and gene expressions related to meat quality.

Keywords: Bama mini-pigs; Carcass traits; Growth performance; Meat quality; Plasma metabolites; Probiotics; Synbiotics

Introduction

Microbes inhabited in the gut have strong metabolic activity and play critical roles in regulating the growth and development, nutrient metabolism, immunity response, and health of the host [1]. Previous studies have shown that the intestinal microbiota can affect muscle growth, nutrient metabolism, and muscle fiber type transformation [2], indicating that intestinal microbiota can influence the carcass traits and meat quality through multiple metabolic pathways. Increasing evidence has shown that maternal probiotics supplementation has beneficial effects on offspring piglet's growth and development. For example, dietary *Bacillus* addition during late gestation and lactation has beneficial effects on growth performance and intestinal microbiota modulation of piglets [3]. In addition, dietary prebiotics such as xylo-oligosaccharides (XOS) intervention could also facilitate the proliferation of beneficial microbes and thus improve the growth performance of weaned piglets by regulating intestinal health [4]. However, it has remained unknown how maternal gut microbiota regulates the meat quality of offspring and whether the gut microbiota or their metabolites have positive effects on meat quality. Therefore, maternal gut microbiota intervention through probiotics, prebiotics, and synbiotics addition would be used as a strategy to improve the meat quality of the offspring.

Maternal health and nutritional status during gestation and lactation play a vital role in the growth and development of the fetuses and have potential long-term effects on offspring pigs. Studies have demonstrated that changing maternal nutrition during

gestation and lactation can affect meat color, muscle tenderness, intramuscular fat (IMF), water-holding capacity, muscle fiber type, and muscle metabolism of offspring pigs [5, 6]. Furthermore, fetal and neonatal periods are the most critical periods for skeletal muscle development, which has been completed in the embryonic and fetal stages [7]. The development of postnatal muscle fibers is dependent on the increased diameter and alteration of muscle fiber type composition [8]. Therefore, pregnancy and lactation stages are the window periods to regulate the development of fetal muscle fibers and meat quality. In other words, maternal nutrition intervention during pregnancy and lactation is an effective strategy to improve the growth and development of fetal skeletal muscle and meat quality of offspring pigs.

Our previous studies showed that the addition of maternal synbiotics (including *Lactobacillus plantarum* $\geq 1.0 \times 10^8$ CFU/g, *Saccharomyces cerevisiae* $\geq 0.2 \times 10^8$ CFU/g and XOS) during pregnancy and lactation improved piglet's survival rate, nutrient metabolism, and intestinal barrier permeability, reduced oxidative stress, and modified colonic microbiota composition and metabolic activity in suckling piglets [9, 10]. Based on the above-mentioned findings, we hypothesize that the intervention in the intestinal microbial balance of sows by dietary probiotics or synbiotics might improve the growth performance and meat quality of offspring pigs. Bama mini-pig, as one of the most well-known native mini-pigs in China, has better meat quality and lower muscle growth than commercial pigs [11]. In addition, the Bama mini-pig is a useful animal model for studying high-quality meat. Therefore, the present study used Bama

mini-pig as a model to explore the effects of maternal antibiotic (inhibiting the gut microbiota), probiotics (increasing the beneficial gut microbiota), or synbiotics (increasing the beneficial gut microbiota and their fermenting substrate) addition during pregnancy and lactation on growth performance, carcass traits, meat quality, plasma metabolites, and related gene expression of offspring pigs.

Materials and methods

Animals, diets, and treatments

The present study was conducted at the mini-pig experimental base of Goat Chong located in Shimen Town, Changde City, Hunan Province, China. A total of 64 pregnant Bama mini-pigs during 3-5 parities with initial body weight (BW) of about 90 kg were selected and randomly divided into four groups (16 sows (pens) per group). The dietary treatment groups were represented the control group (fed antibiotic-free basal diet), antibiotic group (added 50 g/t virginiamycin with the basal diet), probiotics group (added 200 mL/d probiotics mixture per animal with the basal diet), and synbiotics group (added 500 g XOS per ton diet + 200 mL/d probiotics mixture per animal with the basal diet). The probiotics mixture was provided by Hunan Lifeng Biotechnology Co., Ltd. (Changsha, Hunan, China), containing *Lactobacillus plantarum* $\geq 1 \times 10^8$ CFU/mL and *Saccharomyces cerevisiae* $\geq 0.2 \times 10^8$ CFU/mL. The XOS was provided by Shandong Longlive Biotechnology Co., Ltd. (Shandong, China), containing xylobiose, xylotriose, and xylotetraose at $\geq 35\%$. The supplementing probiotics mixture was mixed with diets before feeding the sows, and the XOS was added to diets during

feed production. The dose of the probiotics and synbiotics was the recommended dose by the manufacturers.

After insemination, the sows were housed individually in gestation crates (2.2 × 0.6 m) from day 1 to day 105 of pregnancy. The sows were then transferred to farrowing crates (2.2 × 1.8 m) on day 106 of pregnancy, where they were housed until weaning. The sows were fed 0.8, 1.0, 1.2, 1.5, and 2.0 kg of the pregnant diets during 1-15, 16-30, 31-75, 76-90, and 91-105 days of pregnancy, respectively; fed 1.0 kg pregnant diets before a week of parturition and *ad libitum* after three days of parturition; and then fed 2.4 kg lactation diets until weaning. The sows were fed twice daily at 8:00 a.m. and 5:00 p.m., respectively, and water was freely available at all times. The creep feed was provided to the suckling piglets from 7- to 28-day-old. After weaned at 28-day-old, one male piglet and one female piglet close to the average BW per litter were selected and transferred to the nursery house for the subsequent feeding trial. After one week of adaption, four piglets from two litters in the same group were merged into one pen. Four piglets were assigned to one pen with eight pens (replicates) per group. All the piglets were fed the basal diet of the remaining trial. Basal diet composition and nutrient levels for the sows and piglets are presented in **Supplementary Table 1** and **Supplementary Table 2**, respectively. Feeding and management were carried out according to the standard operation of commercial pig farms.

Sample collection

The offspring pigs from each group were fasted for 12 h and weighed at 65-, 95-, and 125-day-old, respectively. Then one pig per pen (a total of eight pigs per group) was selected and sacrificed under commercial conditions using electrical stunning (120 V, 200 HZ) and exsanguination. Blood samples were collected via precaval vein in 10 mL heparinized tubes, centrifuged at 4°C and $3,500 \times g$ for 10 min to obtain plasma, and immediately stored at -20°C for further analysis. After removing the head, legs, tail, and viscera, the carcass was split longitudinally for evaluating carcass traits and meat quality. Then the *longissimus thoracis* (LT) muscle samples were collected, and stored in sealed plastic bags at -20°C to analyze the routine nutrients. In addition, the LT muscle samples (~2 g) were also collected and immediately frozen in liquid nitrogen and stored at -80°C for mRNA analyses.

Determination of growth performance

Feed intake of offspring pigs per pen was recorded daily. The BW of all pigs per pen was weighed at 65-, 95-, and 125-day-old pigs, respectively. The average daily gain (ADG), average daily feed intake (ADFI), and feed/gain ratio (F/G) were calculated during 35–65, 66–95, and 96–125 day-old, respectively.

Measurement of carcass traits

According to the Chinese pig-raising industry standards (GB8467-87, 1988), the left side of each carcass was dissected into the skin, skeletal muscle, bone, and fat. The skeletal muscle, bone, fat, and leaf fat were weighted for calculating their percentages of live BW [tissue weight $\times 2$ (kg)/BW (kg) $\times 100\%$] or ratio to live BW [leaf fat weight

× 2 (g)/BW (kg)]. Backfat thickness (between the sixth and seventh ribs) was measured using a Vernier caliper. The width and height of the LT muscle cross-section were measured using a Vernier caliper for calculating the loin-eye muscle area (width × height × 0.7).

Measurement of meat quality

The subjective marbling and meat color scores of the LT muscle were determined by following the National Pork Producers Council (NPPC) guidelines [12]. Meat color, including L* (lightness), a* (redness), and b* (yellowness) values of the LT muscle were measured using the colorimeter (CR410, Konica Minolta Sensing, Inc., Tokyo, Japan) at 45 min post mortem. The pH at 45 min (pH_{45min}) and 24 h (pH_{24h}) post mortem was measured by using a portable pH meter (Russell CD700, Russell pH Limited, Germany). The drip loss was determined using the “bag method” as previously described [13]. Briefly, the LT muscle samples were stored at 4°C, and then the samples were placed in individual polyethylene vacuum bags and cooked to an internal temperature of 70°C detected by the thermocouple thermometer (Digital Thermometer TP101, Changzhou KB Instruments & Meter Co., Ltd., China) in a water bath at 75°C at 24 h post mortem [14]. Then the cooked samples were cooled to room temperature, dried with a paper towel, and re-weighted for calculating cooking yield [(cooked weight/fresh weight) × 100%]. After the cooking yield determination, the samples were trimmed into shaped stripes with a diameter of 1.27 cm and a length of 20 mm along the direction parallel to the muscle fiber. The stripes were then used to determine the

shear force (N) using a texture analyzer (FTC-TMS/PRO, FTC Corporation, United States) with a load cell of 15 kg and a 200 mm/min crosshead speed.

Chemical composition analysis of the *longissimus thoracis* muscle

The LT muscle samples were minced after weighing and dried in a vacuum-freeze dryer at (20 ± 5) Pa and $-(45 \pm 5)$ °C for 72 h (CHRIST RVC2-25 CDPIUS, Christ Company, Osterode, Germany) to calculate the dry matter (DM) content. The crude protein (CP) content ($N \times 6.25$) was determined using the Kjeldahl method following the standards provided by the Association of Official Analytical Chemists' (AOAC) methods [15]. The intramuscular fat (IMF) content was determined using the Soxhlet extraction method [16].

Approximately 0.1000 g of freeze-dried skeletal muscle powder was hydrolyzed in 10 mL of 6 mol/L HCl solution in a sealed ampoule bottle at 110°C for 24 h. The suspension was diluted to 100 mL using double-distilled water in the volumetric flask [17], and 1 mL of the supernatant was transferred to 1.5 mL centrifuge tubes and evaporated to dryness in a water bath at 65°C. The samples were then dissolved using 1 mL of 0.02 mol/L HCl solution and filtered through a 0.45- μ m membrane prior to analysis of hydrolyzed amino acids contents by an automatic amino acid analyzer (L-8900, Hitachi, Tokyo, Japan) [18].

Medium- and long-chain fatty acids (FA) were identified via the gas-liquid chromatography (7890A, Agilent, California, USA). Briefly, FA were analyzed by FID detector after extracting with the mixture of benzene and petroleum ether and methyl

esterification through potassium hydroxide methanol. The sample pretreatment method was described as previously [19]. The GC conditions were as follows: the injector and detector temperatures were held at 280°C; the initial column temperature held at 100°C for 13 min; increased at 10°C per min to 180°C, and held for 6 min; increased at 1°C per min to 200°C, and held for 20 min; increased at 4°C per min to 230°C, and held for 15 min. Nitrogen was used as the carrier gas and the flow rate was 0.8 mL/min. The inlet temperature was 270°C, the injection volume was 1 µL, and the split ratio was 20:1. The contents of FA were identified by comparison with the retention times of reference standard mixtures (99%, Sigma, St. Louis, MO, USA). Data are expressed as the percentage of the total FA.

Muscular RNA extraction and real-time quantitative PCR analysis

Total RNA of the LT muscle was extracted using the AG RNAex Pro reagent (Accurate Biology, Hunan, China) according to the manufacturers' protocol. The concentration of the extracted RNA was measured using the NanoDrop ND-2000 spectrophotometer (Thermo Fisher Scientific, Waltham, MA, United States), and the purity was ascertained by the A260/A280 ratio. The quality of RNA was evaluated with agarose gel electrophoresis. The total RNA (1000 ng) was reversely transcribed into cDNA using an Evo M-MLV RT Kit with gDNA Clean for qPCR (Accurate Biology, Hunan, China). The RT-PCR analysis was performed on the LightCycler® 480II Real-Time PCR System (Roche, Basel, Swiss) with SYBR® Green Premix Pro Taq HS qPCR Kit (Accurate Biology, Hunan, China). The specific primers of target genes were designed

and synthesized by Sangon Biotech (Shanghai) Co., Ltd., China (**Supplementary Table 3**). The RT-qPCR was performed in a 10 μ L reaction system, including 0.25 μ L of each primer, 5.0 μ L SYBR[®] Green Premix, 2.0 μ L cDNA, and 2.5 μ L of double-distilled water. The PCR cycling conditions were followed according to the instructions of SYBR Green Premix. The relative gene expression levels between different groups were calculated using the $2^{-\Delta\Delta C_t}$ method [20].

Determination of plasma biochemical parameters

The plasma levels of alanine aminotransferase (ALT), alkaline phosphatase (ALP), α -amylase (α -AMS), aspartate aminotransferase (AST), cholinesterase (CHE), lactate dehydrogenase (LDH), albumin (ALB), ammonia (AMM), total protein (TP), urea nitrogen (UN), high-density lipoprotein-cholesterol (HDL-C), low-density lipoprotein-cholesterol (LDL-C), total cholesterol (TC), triglyceride (TG), and glucose (GLU) were determined using commercially available kits (F. Hoffmann-La Roche Ltd, Basel, Switzerland) and the Roche automatic biochemical analyzer (Cobas c311, F. Hoffmann-La Roche Ltd, Basel, Switzerland).

Determination of plasma free amino acids

The plasma samples (800 μ L) were mixed with 8% sulfosalicylic acid in equal proportion, and then stored at 4°C for overnight to precipitate protein. The supernatants were obtained by centrifuging at $8,000 \times g$ for 10 min. The processed samples were then filtered through a 0.22- μ m membrane into sample bottles prior to analysis of free amino acids with an automatic amino acid analyzer (L8900, Hitachi, Tokyo, Japan).

Statistical analysis

The experimental unit was a pen for the ADFI, ADG, and F/G data, and the individual pig was for the other data. All data were analyzed using the SPSS software package (SPSS v. 25.0, SPSS Inc., Chicago IL, USA). The normal distribution of the data was confirmed by the Shapiro-Wilk test before assessing the differences among the four groups. The data were analyzed by one-way ANOVA, and differences among the four treatments were compared using the Tukey *post-hoc* test. Data are presented as means with their standard error of the mean (SEM). Differences were considered significant if $P < 0.05$.

Results

Growth performance

The effects of probiotics and synbiotics addition in sow's diets on growth performance are shown in **Table 1**. Compared with the antibiotic group, dietary probiotics addition in sow diets increased ($P < 0.05$) the BW of 95-day-old offspring pigs. The ADFI was increased in the probiotics group while decreased in the antibiotic group during 66–95 day-old, when compared with the control group ($P < 0.05$). Moreover, the antibiotic group had higher F/G compared with the control group and higher ADFI compared with the other three groups during 96–125 day-old ($P < 0.05$).

Carcass traits

The carcass traits of offspring pigs are presented in **Table 2**. At 65-day-old, the probiotics group had a higher ($P < 0.05$) carcass weight compared with the antibiotic

and synbiotics groups, while the backfat thickness was increased ($P < 0.05$) in the probiotics group compared with the control and antibiotic groups. At 95-day-old, the leaf fat ratio was lower ($P < 0.05$) in the antibiotic and probiotics groups compared with the control and synbiotics groups, while the loin-eye area was higher ($P < 0.05$) in the synbiotics group compared with the antibiotic group. Moreover, the antibiotic group had a lower fat percentage than the other three groups and lower carcass weight than the control group at 95-day-old ($P < 0.05$). At 125-day-old, dietary antibiotic, probiotics, and synbiotics addition increased the fat percentage and backfat thickness, while dietary synbiotics addition decreased the muscle percentage of pigs compared with the pigs in the control group ($P < 0.05$). Moreover, dietary synbiotics addition decreased ($P < 0.05$) the loin-eye area of pigs compared with the three groups at 125-day-old.

Meat quality

The effects of dietary probiotics and synbiotics addition in sow diets on meat quality of offspring pigs are shown in **Table 3**. Compared with the control and antibiotic groups, drip loss in the probiotics and synbiotics groups was lower ($P < 0.05$), while cooking yield in the probiotics group was higher ($P < 0.05$) at 65-day-old. In addition, the L^* value was higher ($P < 0.05$) in the probiotics group, and the shear force was lower ($P < 0.05$) in the synbiotics group compared with the other three groups at 65-day old. At 95-day-old, the a^* value was lower ($P < 0.05$) in the probiotics group but was higher ($P < 0.05$) in the synbiotics group compared with the control and antibiotic groups, and pH_{45min} was higher ($P < 0.05$) in the probiotics group compared with the control and

synbiotics group. Moreover, the L^* value in the probiotics group was higher ($P < 0.05$) than the synbiotics groups at 95-day-old. At 125-day-old, the L^* value was lower in the synbiotics group compared with the control and probiotics groups, while the b^* value was higher in the probiotics group compared with the antibiotic and synbiotics groups ($P < 0.05$). Moreover, the shear force in the probiotics and synbiotics groups was lower than the control and antibiotic groups, while cooking yield and shear force were higher in the antibiotic group than the other three groups at 125-day-old ($P < 0.05$).

Amino acid contents of *longissimus thoracis* muscle

The contents of amino acids in the LT muscle are presented in **Table 4**. Compared with the control and antibiotic groups, His content in the LT muscle was higher in the probiotics and synbiotics groups, while asparagine (Asp) and glycine (Gly) contents were lower in the probiotics group at 65-day-old ($P < 0.05$). At 95-day-old, compared with the control group, arginine (Arg) content in the LT muscle was higher in the antibiotic, probiotics, and synbiotics groups, as well as the Asp and TAA contents in the probiotics and synbiotics groups, while the histidine (His) content in the LT muscle was lower in the probiotics group ($P < 0.05$). Moreover, isoleucine (Ile) content in the probiotics and synbiotics groups and lysine (Lys) content in the synbiotics group were higher compared with the control and antibiotic groups, while proline (Pro) content in the synbiotics groups was lower compared with the antibiotic group ($P < 0.05$). At 125-day-old, Asp and leucine (Leu) contents in the antibiotic and probiotics groups and the phenylalanine (Phe) content in the synbiotics group were higher ($P < 0.05$) in the LT

muscle compared with the control group. Moreover, serine (Ser) and His contents in the LT muscle were higher ($P < 0.05$) in the synbiotics group compared with the other three groups at 125-day-old.

Fatty acid contents of *longissimus thoracis* muscle

The effects of dietary probiotics and synbiotics addition in sow diets during pregnancy and lactation on amino acid contents in the LT muscle of offspring pigs are shown in **Table 5**. At 65-day-old, compared with the control group, the contents of C18:2n6c and PUFA in the antibiotic and probiotics groups and the contents of C10:0, C12:0, and C14:0 in the synbiotics group were increased ($P < 0.05$) in the LT muscle of pigs, whereas the contents of C16:0 and C20:1 in the probiotics group were decreased ($P < 0.05$) in the muscle of pigs. In addition, the content of C24:0 was increased ($P < 0.05$) in the probiotics group, while the contents of C18:1n9c, C20:0, and SFA in the probiotics group were decreased ($P < 0.05$) compared with the other three groups. Moreover, the content of C10:0 was increased ($P < 0.05$) in the synbiotics group compared with the other three groups, and the content of IMF was decreased ($P < 0.05$) in the probiotics group compared with the antibiotic and synbiotics groups. At 95-day-old, the content of C10:0 in the probiotics and synbiotics groups and the content of C14:0 in the probiotic group were increased ($P < 0.05$) in the LT muscle of pigs, while the content of C20:1 in the antibiotic and synbiotics groups was decreased ($P < 0.05$) compared with the control group. In addition, the content of C12:0 was increased while the content of C16:1 was decreased in the antibiotic, probiotics, and synbiotics groups

compared with the control group ($P < 0.05$). Moreover, the contents of UFA and MUFA were increased ($P < 0.05$) in the probiotics group compared with the other three groups at 95-day-old. At 125-day-old, the contents of C15:0 in the probiotics and synbiotics groups, C17:0 in the probiotics group, C18:2n6c in the synbiotics group, and C18:1n9t in the antibiotic, probiotics, and synbiotics groups were decreased in the LT muscle of pigs compared with the control group. In addition, the contents of C16:1 in the probiotics group and IMF in the synbiotics group were increased ($P < 0.05$) compared with the other three groups.

The mRNA expression of myosin heavy chain isoforms, myogenic regulatory factors, and lipid metabolism related genes in *longissimus thoracis* muscle

The effects of probiotics and synbiotics addition in sow diets on mRNA expression of MyHC isoforms, MRFs, and lipid metabolism related genes in the LT muscle of offspring pigs at 65-, 95-, and 125-days are shown in **Figure 1**. Compared with the control group, the mRNA expression of *MyHC IIa* in the antibiotic, probiotics, and synbiotics groups was up-regulated ($P < 0.05$), while the mRNA expressions of *MyHC IIx* and *MyHC IIb* in the probiotics group were down-regulated ($P < 0.05$) in the LT muscle of pigs at 65-day old (**Figure 1 A–B**). Moreover, the mRNA expression of *MyHC I* was up-regulated ($P < 0.05$) in the probiotics group compared with the other three groups and the mRNA expression of *Myf6* was down-regulated ($P < 0.05$) in the antibiotic group compared with the probiotics group at 65-day-old (**Figure 1 A–B**). At 95-day-old, the mRNA expression of *MyHC IIb* and *Myf5* in the LT muscle were up-

regulated ($P < 0.05$) in the probiotics and synbiotics groups compared with the control and antibiotics groups. The mRNA expression of *MyHC I* and *Myf6* in the LT muscle were up-regulated ($P < 0.05$) in the synbiotics group, while the expression of *MSTN* was down-regulated ($P < 0.05$) when compared with the other three groups (**Figure 1 A–B**). At 125-day-old, the mRNA expression of *Myf6* in the antibiotic, probiotics, and synbiotics groups and the mRNA expression of *MyHC IIa* in the antibiotic and synbiotics groups were up-regulated ($P < 0.05$) in the LT muscle compared with the control group. In addition, the mRNA expression of *MyOG* in the probiotics and synbiotics groups was down-regulated ($P < 0.05$) compared with the control and antibiotics groups. Moreover, the mRNA expression of *MyHC I* and *Myf5* were up-regulated ($P < 0.05$) in the antibiotic group compared with the control and probiotics groups (**Figure 1 A–B**).

As shown in **Figure 1 C–D**, at 65-day-old, the mRNA expression of stearoyl-CoA desaturase (*SCD*) in the LT muscle was down-regulated ($P < 0.05$) in the antibiotic, probiotics, and synbiotics groups compared with the control group, whereas the mRNA expression of lipoprotein lipase (*LPL*) was up-regulated ($P < 0.05$) in the probiotics group compared with the other three groups. At 95-day-old, the mRNA expression of *LPL* in the antibiotic, probiotics, and synbiotics groups and the mRNA expression of acetyl-CoA carboxylase (*ACC*) in the probiotics group were up-regulated ($P < 0.05$) compared with the control group. Moreover, the mRNA expression of fatty acid synthase (*FASN*) in the probiotics and synbiotics groups and the mRNA expression of

SCD in the synbiotics group were up-regulated ($P < 0.05$), compared with the control and antibiotic groups. At 125-day-old, the mRNA expression of *LPL* was up-regulated ($P < 0.05$) in the antibiotic, probiotics, and synbiotics groups compared with the control group. The mRNA expression of *ACC* was up-regulated in the antibiotic and synbiotics groups and down-regulated in the probiotics group compared with the control group. Moreover, the mRNA expressions of *FASN* and *SCD* were up-regulated ($P < 0.05$) in the antibiotic group compared with the other three groups, while the mRNA expression of hormone-sensitive triglyceride lipase (*LIPE*) was down-regulated compared with the control group.

Plasma biochemical parameters

To evaluate the effects of maternal probiotics or synbiotics addition in sows' diets on offspring pigs, we measured the plasma biochemical parameters at 65-, 95-, and 125-day-old, and the results are presented in **Table 6**. At 65-day-old, compared with the control group, the plasma activity of α -AMS in the antibiotic, probiotics, and synbiotics groups, while the plasma activity of LDH was increased in the antibiotic group and decreased in the probiotic group ($P < 0.05$). The concentrations of LDL-C and TC were increased in the antibiotic group while decreased in the synbiotics group compared with the control group ($P < 0.05$). In the synbiotics group, the concentration of HDL-C was increased compared with the other three groups, while the concentration of Glu was decreased compared with the control and probiotics groups ($P < 0.05$). Moreover, the concentrations of ALB in the antibiotic group and CHE in the probiotics group were

decreased ($P < 0.05$) compared with the other three groups. At 95-day-old, the plasma activities of AST and LDH in the antibiotic and probiotics groups, the concentration of GLU in the antibiotic, probiotics, and synbiotics groups, and concentration of TG in the synbiotics group were decreased ($P < 0.05$) compared with the control group. Compared with the control and antibiotic groups, the plasma CHE activity and UN concentration were decreased ($P < 0.05$) in the probiotics and synbiotics groups. Moreover, the plasma concentration of AMM was decreased ($P < 0.05$) in the probiotics group compared with the other three groups. At 125-day-old, the plasma concentration of HDL-C was increased ($P < 0.05$), whereas the AST and LDH activities were decreased ($P < 0.05$) in the antibiotic and probiotics groups compared with the control group. The plasma concentration of AMM was decreased ($P < 0.05$) in the antibiotic, probiotics, and synbiotics groups, while the plasma activity of α -AMS was increased ($P < 0.05$) in the antibiotic and synbiotics groups, when compared with the control group. Moreover, the plasma concentration of TP in the antibiotic group was decreased ($P < 0.05$), and the plasma concentration of TG in the synbiotics group was increased ($P < 0.03$) compared with the other three groups.

Plasma free amino acid concentration

Table 7 presents the effects of maternal probiotics or synbiotics addition in sow's diets in offspring pigs' plasma free amino acid concentration. At 65-day-old, the plasma histidine (His) concentration in the probiotics group, the hydroxy-proline (Hypro) concentration in the antibiotic, probiotics, and synbiotics groups, and the β -

389 aminoisobutyric acid (β -AiBA) concentration in the antibiotic and synbiotics groups
390 were increased ($P < 0.05$), whereas the plasma Gly, Ile, sarcosine (Sar), and taurine
391 (Tau) concentrations in the antibiotic and probiotics groups and the Leu concentration
392 in the probiotics group were decreased ($P < 0.05$), compared with the control group.
393 Compared with the control and antibiotic groups, the plasma citrulline (Cit) and
394 cystathionine (Cysthi) concentrations were increased ($P < 0.05$) in the synbiotics group,
395 while the plasma alanine (Ala) concentration was decreased ($P < 0.05$) in the probiotics
396 group. The plasma γ -amino-n-butyric acid (γ -ABA) concentration was increased in the
397 synbiotics group compared with the other three groups, while the plasma tyrosine (Tyr)
398 concentration was decreased and the plasma hydroxy-lysine (Hyls) was increased in
399 the probiotics group compared with the other three groups ($P < 0.05$). However, the
400 antibiotic group had increased ($P < 0.05$) plasma threonine (Thr) and Pro concentrations
401 compared with the other three groups.

402 At 95-day-old, the plasma Ile, Leu, Cit, Tau, α -aminoadipic acid (α -AAA), α -ABA,
403 β -alanine (β -Ala), and γ -ABA concentrations were decreased, and the plasma γ -amino-
404 n-butyric acid (β -AiBA) was increased in the antibiotic, probiotics, and synbiotics
405 groups, compared with the control group ($P < 0.05$). In addition, compared with the
406 control group, the plasma β -AiBA concentration was increased, and the ethanolamine
407 (EOH₂NH₂) concentration was decreased in the probiotics and synbiotics groups ($P <$
408 0.05). Compared with the control and antibiotic groups, the plasma Sar concentration
409 was increased, and the EOH₂NH₂ was decreased in the probiotics and synbiotics groups,

as well the plasma Cysthi concentration was increased in the synbiotics group ($P < 0.05$). Moreover, the plasma Hylys concentration was increased, and the plasma anserine (Ans) concentration was decreased in the synbiotics groups, compared with the other three groups. However, the antibiotic group had increased ($P < 0.05$) plasma 1-Methyl-histidine (1-Mehis), EOHNH₂, and ornithine (Orn) concentrations compared with the other three groups.

At 125-day-old, the plasma Ans and methionine (Met) concentrations in the antibiotic and probiotics groups, the plasma valine (Val) and Leu concentrations in the antibiotic and synbiotics groups were increased, compared with the control group. The plasma α -ABA concentration was increased, whereas the Orn concentration was decreased in the antibiotic, probiotics, and synbiotics groups compared with the control group ($P < 0.05$). Compared with control and antibiotic groups, the plasma Cysthi concentration was increased in the synbiotics group, while the plasma Ser concentration was decreased in the probiotics and synbiotics groups ($P < 0.05$). Moreover, the plasma Asp and His concentrations were increased in the probiotics group, and the plasma EOHNH₂ concentration was decreased in the synbiotics group, when compared with the other three groups ($P < 0.05$). However, the antibiotic group had increased ($P < 0.05$) plasma Thr, Ala, Arg, Gly, Pro, Ser, Tau, Tyr, and β -AiBA concentrations compared with the other three groups.

Discussion

There is growing scientific and industrial interest for prebiotics, probiotics, and synbiotics addition in pig production [21, 22]. Numerous studies showed that dietary probiotics or synbiotics could improve the health status and production performance of pigs by modulating intestinal microbiota [23, 24]. Therefore, the present study aimed to determine the effects of maternal gut microbiota intervention via dietary probiotics or synbiotics addition on the growth performance, carcass traits, meat quality, and metabolites of their offspring pigs. Our findings indicated that dietary probiotics or synbiotics addition in Bama mini-pigs' diets could improve growth performance, meat quality, and the body's metabolism of offspring pigs.

Dietary probiotics or synbiotics addition in diets have been widely used in livestock production. Recent studies have found that can improve the growth performance in growing-finishing pigs [25], such as dietary *Lactobacillus plantarum* ZLP001 addition could increase the ADFI of weaning piglets [26]. In the present study, maternal probiotics or synbiotics addition did not affect the growth performance of offspring pigs, except for an increase of ADFI in the probiotics group during the 66–95 day-old. A possible reason for the inconsistent growth performance of the present study might be related to the pig breeds. Moreover, Bergamaschi et al. (2020) demonstrated that three breed pigs present different ADFI due to their different gut microbiota composition [27]. Our previous study also showed that dietary synbiotics (including *Lactobacillus plantarum* $\geq 1.0 \times 10^8$ CFU/g, *Saccharomyces cerevisiae* $\geq 0.2 \times 10^8$ CFU/g and XOS) addition can alter the abundance, diversity, and composition of gut

microbiota in pregnant and lactating sows [10]. However, the present study also found that maternal antibiotic addition significantly decreased the ADFI of offspring pigs during 66–95 day-old and increased F/G during 96–125 day-old, which may be related to the adverse effects of antibiotic use during pregnancy on the offspring [28]. A previous study also indicated that maternal antibiotic addition could alter the maternal and fetus microbiome in utero and during the postnatal period through maternal-fetus interaction, thereby affecting the health of offspring [29]. Therefore, the adverse effect of maternal antibiotic addition on the growth performance of offspring needs to be further studied.

Carcass traits and meat quality are the major factors that influence the meat flavor, tenderness, juiciness, and overall consumer acceptance. In the present study, maternal probiotics or synbiotics addition increased the backfat thickness and fat percentage of offspring pigs at 125-day-old along with the antibiotic, while probiotics addition increased backfat thickness at 65-day-old, suggesting that these additives could improve body fat deposition and then improve the meat tenderness in the 125-day-old pigs. Generally, the loin-eye area is positively related to the lean meat rate and negatively related to backfat thickness. However, the present study showed a decrease in the loin-eye area and lean meat rate in the synbiotics group at 125-day-old, indicating that maternal synbiotics has no impact on lean meat. Previous studies also found that dietary XOS addition has no significant effect on lean meat [30, 31]. This inconsistency

may be correlated with the pig breed. Bama mini-pig belongs to the fatty breed of pigs, which has higher fat content than the Landrace pigs [19].

Meat color is an important sensory index because it affects consumers' first impression of the meat, and it is generally evaluated by redness, lightness, and yellowness values [32]. The high-quality meat has higher redness values and lower lightness and yellowness values [33]. In the present study, maternal synbiotics addition increased the redness values at 95-day-old and decreased the lightness values at 125-day-old in the LT muscle of offspring pigs. Moreover, maternal probiotics decreased the lightness and redness values of LT muscle at 65- and 95-day-old, respectively. Previous studies have reported that dietary synbiotics (including yeast cell wall, XOS, *Clostridium butyricum*, *Bacillus licheniformis*, and *Bacillus subtilis*) had no effects on the redness and lightness values [34], while dietary probiotics addition could increase the redness values but not lightness values [32]. However, the present study suggesting that maternal synbiotics addition could improve the sense-impression of pork, while probiotics addition has no positive effect on meat color. These inconsistent findings might be related to the feeding stage and the type and dose of probiotics or synbiotics.

Additionally, the results of this study revealed that maternal probiotics or synbiotics addition also improved the meat quality by increasing pH, water holding capacity, and cooking yield and decreasing the shear force in the LT muscle of offspring pigs. After slaughter, due to glycolysis, the accumulation of lactic acid in the muscle leads to a decrease in pH, which is highly correlated with the drip loss and shear force

[35]. Drip loss can reflect the water-holding capacity of muscle and is also an important factor affecting meat quality [36], while shear force is correlated with meat tenderness (50). In the present study, maternal probiotics addition increased pH_{45min} at 95-day-old and cooking yield at 65-day-old, while maternal probiotics or synbiotics addition increased water holding capacity at 65-day-old and decreased shear force at 125-day-old. However, maternal antibiotic addition showed an increased shear force of the LT muscle at 125-day-old. A previous study reported that drip loss usually ranges from 2% to 10% when the meat is cut into slices [37], which is consistent with the present study (ranges 2.78%–6.32%). The results were also consistent with the previous studies by Suo et al. (2012), who demonstrated that *Lactobacillus plantarum* ZJ316 addition improved pH_{45min} [38], and Zhou et al. (2010), who reported that *Bacillus coagulans* could affect meat quality by decreasing drip loss [39]. Thus, the results of the present study indicated that maternal probiotics addition could decrease the lactic acid accumulation by improving muscle glycolysis, while maternal probiotics or synbiotics addition could increase water holding capacity and cooking by reducing drip loss, cooking loss, and shear force and thereby improve meat quality.

Changes in the nutrient contents of muscular tissue, especially the contents of IMF and CP, could directly affect the sensory properties and nutritional values of meat [40]. Moreover, the IMF is a major quality trait of meat, of which content influences the consumers' perceptions of cooked pork palatability [41]. Fernandez et al. (1999) demonstrated that the tenderness, juiciness, color, and flavor of meat were substantially

improved with the increase in IMF content[42]. In the present study, maternal synbiotics addition increased the IMF content of LT muscle at 125-day-old, indicating that the meat quality was improved by maternal synbiotics addition. The change in IMF content of LT muscle is consistent with the change of shear force in LT muscle because the IMF content has a negative correlation with the shear force [43]. Moreover, the higher IMF content can improve the taste of meat [44].

Amino acids play pivotal roles in the growth, development, reproduction, and health of animals. Moreover, the composition and contents of amino acids in muscle could represent the protein quality and nutritional value of meat [45]. In the present study, dietary probiotic or synbiotics addition significantly increased the TAA contents in the LT muscle at 95-day-old, suggesting that the nutritional value of pork of growing pigs was improved by increasing amino acid deposition. Several AA play key roles in the aroma and flavor profiles of muscle [46]. For example, Arg, Leu, Ile, Val, Phe, Met, and His present a bitter taste; Glu and Asp present a pleasant fresh taste; and Gly, Ala, and Ser present a sweet taste [47]. In the present study, maternal probiotics or synbiotics addition increased several AA contents, including His, Arg, Asp, Leu, Ser, and Phe, at different stages in the LT muscle. These changes could improve the flavor of LT muscle of offspring pigs. A previous study also indicated that dietary *Clostridium butyricum* addition improved the flavor of the duck meat through altering FAA content [48]. Free AA are the main direct source of amino acids for muscle protein synthesis and the key index of protein renewal [49]. Plasma free AA profile reflects the sum of metabolic

flow of nutrients and their metabolites from all tissues and organs [50]. Plasma free AA profile also reflects the dynamics state of the metabolic flux of AAs absorbed from the small intestine, as well as the rates of their utilization and intracellular protein turnover in the whole body [51]. For example, Gly has crucial roles in nutrition and metabolism, and protein synthesis accounts for 80% of whole-body glycine needs by growing animals [52]. Branched-chain AA, including Leu, Ile, and Val, have an impact on the regulation of energy homeostasis and nutrition metabolism [53]. Our results showed that plasma Gly, Ile, Leu, and Tau concentrations were decreased in the probiotics or synbiotics groups at 65- or 125-day-old, suggesting that maternal probiotics or synbiotics addition attenuates the breakdown of protein in muscle and then promotes the AA deposition in the muscle. In addition, the present study also showed that maternal probiotics addition decreased the plasma Asp, Ala, Sar, Tyr, Car, and His concentrations, while probiotics or synbiotics addition decreased the plasma Orn, Cit, α -AAA, α -ABA, β -Ala, and γ -ABA concentrations at different stages of age, suggesting that maternal probiotics and synbiotics addition could improve the protein synthesis of the body.

Plasma biochemical parameters reflect the physiological and nutritional status of the animal [54]. The ALT and AST activities can reflect the status of protein synthesis and catabolism, and the increased activities were related to the improvement of amino acid metabolism [55]. The AMM and UN concentrations accurately reflect the status of protein metabolism and AA balance. The present study showed that maternal

probiotics or synbiotics addition increased ALT activity and decreased AMM and UN concentrations at different stages. These results indicated that maternal probiotics or synbiotics addition could promote the balance of AA and improve the utilization of protein and then the deposition of protein. The rate of lipid utilization could be reflected by the TC, TG, HDL-C, and LDL-C [56]. In the present study, maternal synbiotics addition increased HDL-C, LDL-C, and TC concentrations at 65-day-old and decreased TG concentration at 95-day-old. However, maternal antibiotic addition decreased the concentrations of LDL-C and TC at 65-day-old. These findings suggested that maternal synbiotics improved the lipid metabolism of offspring pigs, while maternal antibiotic addition had a negative effect on the lipid metabolism. The plasma levels of LDH and GLU can reflect energy and glucose metabolism, respectively. The present study showed that LDH activity was decreased in the probiotics group at 95- and 125-day-old, GLU concentration was decreased in the synbiotics group at 65-day-old, and in the probiotics and synbiotics group at 95-day-old. Therefore, the results indicated that maternal probiotics addition improved the energy and glucose metabolism of offspring pigs, while maternal synbiotics addition improved glucose metabolism.

The FA composition profoundly affects the nutritional value, organoleptic properties, and eating quality of pork [57, 58]. The C14:0, C16:0, C16:1n7, C18:0, C18:1n9, and C18:2n6 are the primary FA in pork [59]. In the present study, maternal probiotics addition increased the C18:2n6c, MUFA, and UFA contents in the LT muscle at different stages. Similarly, previous studies also found that dietary probiotics,

such as *Lactobacillus amylovorus* and *Enterococcus faecium* could improve the FA profiles of pork by enhancing the contents of C18:2n6c, MUFA, and PUFA [60]. These alterations indicated that maternal probiotics could improve the primary FA in the muscle of offspring pigs, which may be associated with the favorable changes in the gut microbiota after probiotics addition [61]. The FA profiles of pork can be improved by increasing UFA and decreasing SFA contents in the muscle [60]. Moreover, meat with lower SFA contents could reduce the risk of cardiovascular heart diseases [62]. In the present study, maternal probiotics addition decreased the SFA content at 65-day-old, suggesting that the nutritional value of meat was improved by maternal probiotics addition. Cameron et al. (2000) indicated that the C16:1 content was positively correlated with meat flavor [63]. In our study, maternal probiotics or synbiotics addition increased the C16:1 content at 95-day-old, suggesting that these additives could improve the pork flavor of offspring pigs. In addition, maternal probiotics or synbiotics addition decreased the C18:1n9t content at 125-day-old, which is a kind of trans FA and has adverse effects on human health [64]. Consequently, maternal probiotics or synbiotics addition could improve the meat quality and nutritional value of offspring pigs, which would have beneficial effects on human health.

The muscle fiber type is mainly defined by the myosin heavy chain (MyHC) isoforms [65], and the fiber type composition is largely responsible for the determination of meat quality [66]. The higher proportion of *MyHC I* and *MyHC IIa* fibers are related to the excellent meat quality [67]. In the present study, the expressions

of *MyHC I* and *MyHC IIa* were up-regulated in the probiotics or synbiotics groups at different stages. In addition, the expressions of *MyHC IIb* and *MyHC IIx* were down-regulated in the synbiotics group at 65-day-old. The MRF gene family, including *MyoD*, *MyoG*, *Myf5*, and *Myf6*, plays dominant roles in muscle fiber formation, muscle maturation, and functional perfection of muscle fibers [68]. Myostatin (*MSTN*), a negative regulator of myogenesis, can inhibit muscle growth and development [69]. Previous studies indicated that the expression of the MRF gene family affected the expression of *MyHC* gene isoforms [70], and the *MSTN* plays an important role in the muscle fiber-type conversion [71]. In the present study, maternal probiotics and synbiotics addition up-regulated the *Myf5* and *Myf6* mRNA levels at 95- and 125-day-old, respectively; whereas synbiotics down-regulated the *MSTN* mRNA level at 95-day-old. Therefore, these findings indicated that maternal probiotics or synbiotics addition had positive effects on enhancing muscle growth and altering muscle fiber type composition.

Lipogenesis and lipolysis are major factors affecting fat accumulation in adipose tissue and animal products. The *FASN* and *ACC* could modulate fat deposition in animals by regulating FA synthesis [19]. The *SCD* is involved in the FA biosynthesis and composition [72]. In the present study, maternal probiotics or synbiotics addition up-regulated the *ACC*, *SCD*, and *FASN* mRNA levels at different age stages of offspring pigs. These findings suggested that maternal probiotics or synbiotics addition improved the fat deposition and FA composition in the LT muscle of offspring pigs. The *LPL*, the

critical lipid uptake gene, encodes a protein that participates in the process of fatty acid flux into adipocytes clustered along myofiber fasciculi in the muscle and then provides the appropriate substrate for IMF synthesis [73]. A previous study also indicated that the expressions of *FASN*, *SCD*, and *LPL* have a positive association with the IMF deposition [74]. In the present study, the beneficial effect of maternal probiotics or synbiotics addition on the deposition of IMF could be elucidated by the up-regulation of *LPL* mRNA expression level at 95- and 125-day-old. This finding was also consistent with the increased IMF content of the LT muscle in the present study. Moreover, the *LIPE* was found to participate in the lipolysis and negatively correlated with the IMF deposition [74]. Our results also showed that maternal antibiotic addition not only up-regulated the expression levels of *FASN*, *LPL*, *SCD*, and *ACC*, but also up-regulated *LIPE* expression at 125-day-old. Thus, indicating that antibiotic addition does not have the positive effects on the lipid metabolism of LT muscle.

Conclusions

In summary, maternal synbiotics addition showed only the improvement in daily feed intake, while maternal antibiotics addition had adverse effects on the growth performance of offspring pigs. Dietary probiotics or synbiotics addition during pregnancy and lactation could improve offspring piglets' body metabolism by promoting glucose, amino acids, and energy metabolism. Furthermore, maternal probiotics or synbiotics addition could increase meat quality and nutritional value of meat, including the increase of fat or protein deposition, the improvement of sensory

639 impression, and the alteration of amino acids and fatty acids profiles, by improving the
640 composition of muscle fiber type and growth, and lipid metabolism. However, maternal
641 antibiotic addition had no effects on the lipid metabolism of LT muscles of offspring
642 pigs. Collectively, maternal probiotics or synbiotics could serve as a maternal
643 nutritional intervention strategy to improve feed intake, the body's metabolism, and
644 meat quality of offspring pigs, which are better than the antibiotic.

645 **Abbreviations**

646 1-Mehis, 1-methyl-histidine; 3-Mehis, 3-methyl-histidine; ACC, acetyl-CoA
647 carboxylase; ADG, average daily gain; ADFI, average daily feed intake; Ala, alanine;
648 ALT, alanine aminotransferase; ALP, alkaline phosphatase; ALB, albumin; AMM,
649 ammonia; Ans, anserine; Arg, arginine; Asp, aspartate; AST, aspartate
650 aminotransferase; BW, body weight; Car, carnosine; CHE, cholinesterase; Cit,
651 citrulline; Cysthi, cystathionine; Cys, cysteine; CP, crude protein; DM, dry matter;
652 EOHNH₂, ethanolamine; EAA, essential amino acids; FAA, flavor amino acids; FA,
653 fatty acids; F/G, feed/gain ratio; FASN, fatty acid synthase; Glu, glutamate; GLU,
654 glucose; Gly, glycine; HDL-C, high density lipoprotein-cholesterol; His, histidine;
655 Hylys, hydroxy-lysine; Hypro, hydroxy-proline; IMF, intramuscular fat; Ile, isoleucine;
656 LDH, lactate dehydrogenase; LDL-C, low density lipoprotein-cholesterol; Leu, leucine;
657 LIPE, hormone-sensitive triglyceride lipase; LT, *longissimus thoracis*; LPL, lipoprotein
658 lipase; Lys, lysine; Met, methionine; MRFs, myogenic regulatory factors; MUFA,
659 monounsaturated fatty acid; Myf5, myogenic factor 5; Myf6, myogenic factor 6; MyHC,

660 myosin heavy chain; *MyOG*, myogenin; *MSTN*, myostatin; NEAA, non-essential amino
661 acids; Orn, ornithine; Phe, phenylalanine; Pro, proline; PUFA, polyunsaturated fatty
662 acids; Sar, sarcosine; *SCD*, stearyl-CoA desaturase; Ser, serine; SFA, saturated fatty
663 acid; *SREBP-1*, sterol-regulatory element-binding protein-1; TAA, total amino acids;
664 Tau, taurine; TC, total cholesterol; TG, triglyceride; Thr, threonine; TP, total protein;
665 Tyr, tyrosine; UFA, unsaturated fatty acid; UN, urea nitrogen; Val, valine; XOS, xylo-
666 oligosaccharides; α -AAA, α -aminoadipic acid; α -ABA, α -amino-n-butyric acid; α -
667 AMS, α -amylase; β -Ala, β -alanine; β -AiBA, β -aminoisobutyric acid; and γ -ABA, γ -
668 amino-n-butyric acid.

669 **Authors' contributions**

670 XK and YY conceived and design the experiment and revised the manuscript. QZ, MS,
671 MA, and CM performed the animal feeding experiment, sample collection, and sample
672 analysis. QZ analyzed the data and wrote the manuscript. All the authors read and
673 approved the final manuscript.

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Declarations

Ethics approval and consent to participate

The animal procedures in the present study followed the Chinese Guidelines for Animal Welfare and experimental protocols approved by the Animal Care and Use Committee of the Institute of Subtropical Agriculture, Chinese Academy of Science.

Consent for publication

Not applicable.

Competing interests

The authors declared that no conflict of interest.

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Fig. 1 Effects of probiotics or synbiotics addition in sows' diets on mRNA expression of myosin heavy chain (MyHC) isoforms (A), myogenic regulatory factors (MRFs)(B), and lipid metabolism related genes (C and D) in the *longissimus thoracis* muscle of offspring pigs at 65-, 95-, and 125-day-old. 65 d, 65-day-old; 95 d, 95-day-old; 125-d, 125-day-old. *ACC*, acetyl-CoA carboxylase; *FASN*, fatty acid synthase; *LIPE*, hormone-sensitive triglyceride lipase; *LPL*, lipoprotein lipase; *Myf5*, myogenic factor 5; *Myf6*, myogenic factor 6; *MyOG*, myogenin; *MSTN*, myostatin; *SCD*, stearoyl-CoA desaturase; *SREBP-1*, sterol-regulatory element-binding protein-1.

Table 1

Effects of probiotics or synbiotics addition in sows' diets on growth performance of offspring pigs.

Items	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	<i>P</i> values
Body weight (kg)						
35-day-old	4.97	4.90	4.80	4.66	0.172	0.609
65-day-old	9.37	8.99	9.54	9.26	0.190	0.243
95-day-old	14.05 ^{ab}	12.37 ^b	14.61 ^a	13.32 ^{ab}	0.528	0.032
125-day-old	22.67	26.19	25.36	27.19	1.289	0.097
Average daily gain (kg/d)						
35–65 day-old	0.15	0.14	0.15	0.16	0.005	0.079
66–95 day-old	0.18	0.15	0.18	0.16	0.012	0.284
96–125 day-old	0.27	0.27	0.25	0.26	0.027	0.902
Average daily feed intake (kg/d)						
35–65 day-old	0.41	0.41	0.44	0.41	0.012	0.330
66–95 day-old	0.64 ^b	0.55 ^c	0.75 ^a	0.70 ^{ab}	0.024	<.0001
96–125 day-old	0.92 ^b	1.32 ^a	0.91 ^b	1.10 ^b	0.065	<.0001
Feed/Gain ratio						
35–65 day-old	3.02	2.86	2.68	2.78	0.102	0.136
66–95 day-old	3.56	3.82	3.75	4.25	0.220	0.173
96–125 day-old	3.32 ^b	4.17 ^a	4.00 ^{ab}	3.90 ^{ab}	0.211	0.040

Data are presented as means with pooled SEM. Values in the same row with different superscript letters were significantly different ($P < 0.05$). The replicates per group during 35–65 and 66–95 day-old were 8; during 96–125 day-old, the replicates of the control group, antibiotic group, probiotics group, and synbiotics group were 8, 6, 8, and 6, respectively.

Table 2

Effects of probiotics or synbiotics addition in sows' diets on carcass traits of offspring pigs.

Items	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	<i>P</i> values
Carcass weight (kg)						
65-day-old	5.00 ^{ab}	4.71 ^b	5.27 ^a	4.82 ^b	0.108	0.006
95-day-old	8.25 ^a	6.36 ^b	7.73 ^{ab}	7.32 ^{ab}	0.445	0.037
125-day-old	13.83	16.40	14.60	16.25	0.817	0.091
Muscle percentage (%)						
65-day-old	21.56	21.09	22.49	21.17	0.491	0.191
95-day-old	21.23	20.67	22.00	21.51	0.389	0.130
125-day-old	23.87 ^a	23.11 ^{ab}	23.53 ^a	22.44 ^b	0.236	0.002
Fat percentage (%)						
65-day-old	12.14	12.10	13.31	11.78	0.396	0.052
95-day-old	15.24 ^a	12.47 ^b	15.29 ^a	15.01 ^a	0.662	0.011
125-day-old	17.73 ^b	21.49 ^a	22.28 ^a	20.89 ^a	0.548	<.0001
Bone percentage (%)						
65-day-old	11.80	11.89	11.95	11.98	0.190	0.915
95-day-old	10.13	10.44	10.57	9.99	0.273	0.424
125-day-old	9.15	8.55	9.60	9.25	0.261	0.069
Leaf fat ratio (g/kg)						
65-day-old	6.93	6.04	7.05	6.75	0.376	0.248
95-day-old	11.41 ^a	8.09 ^b	7.77 ^b	11.17 ^a	0.587	<.0001
125-day-old	16.77 ^b	17.88 ^b	21.54 ^a	19.33 ^{ab}	0.925	0.005
Backfat thickness (mm)						
65-day-old	13.27 ^b	12.78 ^b	14.65 ^a	13.90 ^{ab}	0.396	0.014
95-day-old	18.79	16.78	18.46	16.98	0.611	0.060
125-day-old	24.75 ^b	28.81 ^a	27.53 ^a	28.15 ^a	0.832	0.009
Loin-eye muscle area (cm ²)						
65-day-old	4.21	4.29	4.45	4.19	0.200	0.788
95-day-old	4.33 ^{ab}	4.22 ^b	4.39 ^{ab}	5.01 ^a	0.200	0.038
125-day-old	7.20 ^a	7.36 ^a	7.67 ^a	5.57 ^b	0.282	<.0001

Data are presented as means with pooled SEM. Values in the same row with different superscript letters were significantly different ($P < 0.05$). The replicates per group at 65- and 95-day-old were 8. At 125-day-old, the replicates of the control group, antibiotic group, probiotics group, and synbiotics group are 8, 6, 8, and 6, respectively.

Table 3

Effects of probiotics or synbiotics addition in sows' diets on meat quality of offspring pigs.

Items	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	<i>P</i> values
Marbling score						
65-day-old	1.75	1.63	1.38	1.50	0.180	0.502
95-day-old	1.88 ^a	1.38 ^{ab}	1.25 ^{ab}	1.38 ^{ab}	0.190	0.120
125-day-old	1.50	1.67	1.25	1.67	0.193	0.376
Meat color score						
65-day-old	3.13	2.88	2.75	2.50	0.336	0.620
95-day-old	2.50	2.38	2.38	2.63	0.184	0.740
125-day-old	2.75	3.17	2.50	2.83	0.208	0.188
L* value						
65-day-old	51.01 ^a	50.66 ^a	48.11 ^b	50.75 ^a	0.623	0.008
95-day-old	50.16 ^{ab}	49.67 ^{ab}	51.78 ^a	48.50 ^b	0.766	0.041
125-day-old	50.94 ^a	49.49 ^{ab}	52.35 ^a	47.33 ^b	0.993	0.011
a* value						
65-day-old	19.58	19.11	19.47	18.50	0.617	0.605
95-day-old	18.44 ^b	18.01 ^b	17.12 ^c	19.86 ^a	0.226	<.0001
125-day-old	18.14	17.89	17.17	17.16	0.499	0.377
b* value						
65-day-old	6.87	6.82	7.50	7.05	0.192	0.071
95-day-old	6.72	6.59	6.06	6.47	0.213	0.171
125-day-old	7.07 ^{ab}	6.50 ^b	7.30 ^a	6.48 ^b	0.187	0.008
pH _{45min}						
65-day-old	6.55	6.55	6.50	6.52	0.035	0.744
95-day-old	6.54 ^b	6.67 ^{ab}	6.74 ^a	6.55 ^b	0.037	0.002
125-day-old	6.49	6.63	6.66	6.52	0.054	0.069
pH _{24h}						
65-day-old	5.46	5.49	5.61	5.45	0.053	0.134
95-day-old	5.46	5.44	5.46	5.49	0.013	0.088
125-day-old	5.46	5.53	5.50	5.50	0.025	0.245
Drip loss (%)						
65-day-old	6.32 ^a	5.64 ^a	4.41 ^b	2.96 ^c	0.340	<.0001
95-day-old	3.42	3.35	2.98	2.78	0.313	0.437
125-day-old	4.82	3.31	3.82	3.94	0.485	0.182
Cooking yield (%)						
65-day-old	63.01 ^{bc}	60.94 ^c	67.02 ^a	65.22 ^{ab}	1.087	0.003
95-day-old	70.92	69.26	70.99	68.53	0.806	0.098

125-day-old	68.57 ^b	78.41 ^a	68.50 ^b	66.94 ^b	2.331	0.012
Shear force (N)						
65-day-old	61.50 ^b	62.96 ^b	58.73 ^b	75.28 ^a	2.311	<.0001
95-day-old	73.25	64.61	65.74	70.82	2.936	0.143
125-day-old	91.94 ^b	101.74 ^a	77.14 ^c	84.41 ^c	2.516	<.0001

987 Data are presented as means with pooled SEM. Values in the same row with different
988 superscript letters were significantly different ($P < 0.05$). The replicates per group at
989 65- and 95-day-old were 8. At 125-day-old, the replicates of the control group,
990 antibiotic group, probiotics group, and synbiotics group are 8, 6, 8, and 6, respectively.
991 L*, lightness; a*, redness; b*, yellowness.

Table 4

Effects of probiotics or synbiotics addition in sows' diets on amino acids content in the *longissimus thoracis* muscle of offspring pigs (g/100 g fresh muscle).

Item	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	P values
CP						
65-day-old	23.39 ^{ab}	23.80 ^{ab}	24.50 ^a	23.17 ^b	0.318	0.032
95-day-old	22.12	22.65	22.83	22.26	0.316	0.365
125-day-old	22.21 ^{ab}	22.79 ^a	22.06 ^{ab}	21.44 ^b	0.252	0.016
Ala						
65-day-old	1.20	1.20	1.18	1.20	0.031	0.975
95-day-old	1.06	1.14	1.12	1.07	0.031	0.237
125-day-old	1.17	1.23	1.27	1.21	0.029	0.126
Asp						
65-day-old	1.80 ^a	1.80 ^a	1.63 ^b	1.70 ^{ab}	0.038	0.009
95-day-old	1.51 ^b	1.55 ^{ab}	1.68 ^a	1.69 ^a	0.044	0.014
125-day-old	1.76 ^b	1.91 ^a	1.94 ^a	1.77 ^b	0.041	0.004
Glu						
65-day-old	2.63	2.63	2.53	2.54	0.070	0.632
95-day-old	2.63	2.68	2.82	2.81	0.066	0.144
125-day-old	2.84	2.96	3.03	3.00	0.070	0.215
Gly						
65-day-old	1.09 ^a	1.08 ^a	0.96 ^b	1.01 ^{ab}	0.034	0.047
95-day-old	0.95	1.01	1.05	1.06	0.035	0.118
125-day-old	0.98	0.96	1.01	0.96	0.040	0.817
Pro						
65-day-old	0.94	0.96	1.07	0.96	0.039	0.094
95-day-old	1.17 ^{ab}	1.33 ^a	1.14 ^{ab}	0.98 ^b	0.061	0.006
125-day-old	1.04	0.90	0.97	1.07	0.050	0.136
Ser						
65-day-old	0.69	0.71	0.67	0.68	0.020	0.518
95-day-old	0.71	0.74	0.76	0.75	0.017	0.172
125-day-old	0.75 ^b	0.75 ^b	0.78 ^b	0.84 ^a	0.019	0.012
Tyr						
65-day-old	0.71	0.67	0.70	0.70	0.016	0.341
95-day-old	0.63	0.70	0.71	0.70	0.038	0.428
125-day-old	0.75	0.70	0.75	0.80	0.026	0.176
Arg						
65-day-old	1.34	1.31	1.27	1.31	0.026	0.378
95-day-old	1.21 ^b	1.30 ^a	1.35 ^a	1.34 ^a	0.032	0.017

125-day-old	1.34	1.37	1.43	1.38	0.031	0.256
His						
65-day-old	0.80 ^b	0.75 ^b	0.91 ^a	0.79 ^a	0.021	<.0001
95-day-old	0.94 ^a	0.90 ^{ab}	0.82 ^b	0.85 ^{ab}	0.027	0.022
125-day-old	0.89 ^b	0.95 ^b	0.94 ^b	1.08 ^a	0.027	<.0001
Ile						
65-day-old	0.90	0.90	0.83	0.87	0.021	0.056
95-day-old	0.82 ^b	0.83 ^b	0.91 ^a	0.91 ^a	0.021	0.002
125-day-old	0.99	1.04	1.06	0.98	0.024	0.075
Leu						
65-day-old	1.74	1.71	1.61	1.68	0.034	0.079
95-day-old	1.43	1.42	1.50	1.51	0.037	0.252
125-day-old	1.67 ^b	1.80 ^a	1.82 ^a	1.71 ^{ab}	0.040	0.033
Lys						
65-day-old	1.77	1.77	1.64	1.73	0.040	0.105
95-day-old	1.59 ^b	1.58 ^b	1.72 ^{ab}	1.78 ^a	0.047	0.014
125-day-old	1.89	1.96	2.02	1.91	0.045	0.194
Met						
65-day-old	0.53	0.54	0.50	0.49	0.016	0.278
95-day-old	0.54	0.52	0.54	0.53	0.013	0.612
125-day-old	0.62	0.65	0.66	0.66	0.019	0.362
Phe						
65-day-old	0.87	0.84	0.86	0.87	0.021	0.789
95-day-old	0.86	0.81	0.84	0.87	0.020	0.193
125-day-old	0.90 ^b	0.91 ^{ab}	0.96 ^{ab}	1.00 ^a	0.025	0.039
Thr						
65-day-old	0.93	0.93	0.87	0.90	0.018	0.051
95-day-old	0.84	0.88	0.92	0.89	0.024	0.120
125-day-old	0.96	0.97	1.00	0.99	0.024	0.493
Val						
65-day-old	0.97	0.97	0.90	0.95	0.023	0.107
95-day-old	0.96	0.93	0.98	1.00	0.023	0.130
125-day-old	1.08	1.11	1.14	1.12	0.027	0.447
EAA						
65-day-old	9.83	9.72	9.49	9.59	0.195	0.637
95-day-old	9.17	9.18	9.58	9.68	0.216	0.233
125-day-old	10.35	10.76	11.03	10.84	0.234	0.190
NEAA						
65-day-old	9.08	9.06	8.76	8.80	0.214	0.610
95-day-old	8.56	9.14	9.28	9.06	0.229	0.159

125-day-old	9.29	9.42	9.73	9.64	0.226	0.469
FAA						
65-day-old	8.06	8.03	7.57	7.76	0.181	0.211
95-day-old	7.39	7.68	8.01	7.97	0.180	0.075
125-day-old	8.09	8.43	8.66	8.31	0.188	0.176
TAA						
65-day-old	18.90	18.78	18.27	18.39	0.402	0.643
95-day-old	17.25 ^b	18.32 ^{ab}	18.85 ^a	18.74 ^a	0.403	0.035
125-day-old	19.64	20.18	20.76	20.4	0.451	0.303

Data are presented as means with pooled SEM. Values in the same row with different superscript letters were significantly different ($P < 0.05$) The replicates per group at 65- and 95-day-old were 8. At 125-day-old, the replicates of the control group, antibiotic group, probiotics group, and synbiotics group are 8, 6, 8, and 6, respectively.

CP, crude protein; EAA, essential amino acids; NEAA, non-essential amino acids; FAA, flavor amino acids; TAA, total amino acids. The EAA included Arg, arginine; His, histidine; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Phe, phenylalanine; Thr, threonine; and Val, valine. The NEAA included Ala, alanine; Asp, aspartate; Glu, glutamate; Gly, glycine; Pro, proline; Ser, serine; and Tyr, tyrosine; The FAA, included Asp, Glu, Gly, Ala, and Arg.

Table 5

Effects of probiotics or synbiotics addition in sows' diets on medium- and long-chain fatty acids content in *longissimus thoracis* muscle of offspring pigs (%).

Item	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	P values
Intramuscular fat						
65-day-old	2.72 ^{ab}	3.13 ^a	2.32 ^b	3.24 ^a	0.231	0.035
95-day-old	2.62 ^{ab}	2.44 ^{ab}	3.21 ^a	1.52 ^b	0.325	0.009
125-day-old	2.15 ^b	2.07 ^b	1.79 ^b	2.80 ^a	0.197	0.012
C10:0						
65-day-old	0.024 ^b	0.023 ^b	0.021 ^b	0.028 ^a	0.001	0.004
95-day-old	0.022 ^b	0.024 ^{ab}	0.027 ^a	0.026 ^a	0.001	0.028
125-day-old	0.024	0.023	0.026	0.029	0.002	0.145
C12:0						
65-day-old	0.036 ^b	0.039 ^{ab}	0.038 ^{ab}	0.042 ^a	0.001	0.039
95-day-old	0.041 ^a	0.030 ^b	0.035 ^b	0.031 ^b	0.002	<.0001
125-day-old	0.028 ^a	0.023 ^b	0.028 ^a	0.029 ^a	0.001	0.024
C14:0						
65-day-old	0.447 ^{bc}	0.486 ^{ab}	0.423 ^c	0.524 ^a	0.014	<.0001
95-day-old	0.487 ^b	0.514 ^{ab}	0.559 ^a	0.536 ^{ab}	0.017	0.040
125-day-old	0.497	0.505	0.474	0.509	0.027	0.772
C15:0						
65-day-old	0.024	0.029	0.026	0.027	0.001	0.152
95-day-old	0.022	0.024	0.023	0.026	0.001	0.156
125-day-old	0.022 ^a	0.019 ^{ab}	0.017 ^b	0.016 ^b	0.001	0.001
C16:0						
65-day-old	8.137 ^a	8.176 ^{ab}	7.604 ^b	8.355 ^a	0.162	0.017
95-day-old	8.334	8.209	8.643	8.301	0.141	0.172
125-day-old	8.231	8.290	7.796	8.089	0.216	0.356
C16:1						
65-day-old	1.177	1.169	1.091	1.254	0.055	0.253
95-day-old	0.728 ^c	0.906 ^{ab}	0.976 ^a	0.884 ^b	0.025	<.0001
125-day-old	0.785 ^b	0.755 ^b	0.868 ^a	0.757 ^b	0.026	0.013
C17:0						
65-day-old	0.103	0.116	0.100	0.110	0.005	0.183
95-day-old	0.091	0.094	0.094	0.100	0.004	0.514
125-day-old	0.082 ^a	0.078 ^{ab}	0.061 ^b	0.070 ^{ab}	0.006	0.045
C18:0						
65-day-old	4.364	4.207	4.062	4.244	0.085	0.118
95-day-old	5.141	4.824	5.001	4.759	0.103	0.056
125-day-old	4.670	4.440	4.687	4.621	0.102	0.345

C18:1n9c						
65-day-old	8.753 ^a	8.813 ^a	8.023 ^b	8.805 ^a	0.198	0.021
95-day-old	8.820 ^{ab}	8.592 ^b	9.663 ^a	8.894 ^{ab}	0.256	0.035
125-day-old	9.722	9.520	9.567	10.171	0.358	0.610
C18:1n9t						
65-day-old	0.036	0.036	0.035	0.033	0.001	0.500
95-day-old	0.034	0.032	0.035	0.032	0.002	0.538
125-day-old	0.042 ^a	0.035 ^b	0.035 ^b	0.036 ^b	0.002	0.019
C18:2n6c						
65-day-old	4.135 ^b	4.499 ^a	4.626 ^a	4.008 ^b	0.107	0.001
95-day-old	3.179	3.503	3.242	3.165	0.104	0.101
125-day-old	2.603 ^a	2.306 ^{ab}	2.405 ^{ab}	2.150 ^b	0.105	0.037
C20:0						
65-day-old	0.063 ^a	0.064 ^a	0.051 ^b	0.068 ^a	0.003	0.001
95-day-old	0.070	0.074	0.075	0.068	0.003	0.190
125-day-old	0.063	0.057	0.061	0.064	0.003	0.387
C20:1						
65-day-old	0.204 ^b	0.223 ^{ab}	0.181 ^c	0.241 ^a	0.008	<.0001
95-day-old	0.303 ^a	0.223 ^c	0.296 ^a	0.263 ^b	0.010	<.0001
125-day-old	0.097	0.088	0.090	0.085	0.003	0.139
C20:2						
65-day-old	0.163	0.155	0.143	0.156	0.005	0.059
95-day-old	0.153	0.138	0.148	0.138	0.006	0.267
125-day-old	0.105	0.091	0.091	0.088	0.005	0.097
C20:3n6						
65-day-old	0.101	0.108	0.114	0.116	0.005	0.241
95-day-old	0.080	0.090	0.073	0.087	0.006	0.146
125-day-old	0.072	0.073	0.078	0.068	0.006	0.700
C20:4n6						
65-day-old	0.858	0.841	0.936	0.790	0.069	0.522
95-day-old	0.512 ^b	0.762 ^a	0.499 ^b	0.614 ^b	0.049	0.002
125-day-old	0.521	0.562	0.588	0.448	0.051	0.274
C24:0						
65-day-old	0.052 ^b	0.056 ^b	0.074 ^a	0.054 ^b	0.004	0.002
95-day-old	0.051 ^a	0.055 ^a	0.036 ^b	0.046 ^{ab}	0.004	0.010
125-day-old	0.048	0.054	0.057	0.057	0.004	0.401
SFA						
65-day-old	13.267 ^a	13.245 ^a	12.506 ^b	13.271 ^a	0.219	0.049
95-day-old	14.218	13.855	14.391	13.757	0.234	0.204
125-day-old	13.712	12.881	13.271	13.111	0.393	0.496
UFA						
65-day-old	15.777	15.921	15.444	15.608	0.226	0.482

95-day-old	14.318 ^b	14.175 ^b	15.186 ^a	14.553 ^b	0.161	0.001
125-day-old	14.061	13.697	13.528	13.803	0.302	0.604
MUFA						
65-day-old	10.144	10.901	9.373	10.512	0.447	0.119
95-day-old	9.857 ^b	9.568 ^b	10.94 ^a	10.084 ^b	0.267	0.007
125-day-old	10.761	10.465	10.475	10.87	0.405	0.863
PUFA						
65-day-old	5.404 ^b	6.389 ^a	6.400 ^a	5.343 ^b	0.314	0.027
95-day-old	3.891 ^b	4.587 ^a	4.094 ^{ab}	4.198 ^{ab}	0.156	0.028
125-day-old	3.300	3.232	3.192	2.933	0.215	0.674
PUFA/SFA						
65-day-old	0.408	1.164	0.485	0.409	0.311	0.267
95-day-old	0.276	0.328	0.283	0.307	0.015	0.082
125-day-old	0.246	0.244	0.241	0.226	0.020	0.913

Data are presented as means with pooled SEM. Values in the same row with different superscript letters were significantly different ($P < 0.05$). The replicates per group at 65- and 95-day-old were 8. At 125-day-old, the replicates of the control group, antibiotic group, probiotics group, and synbiotics group are 8, 6, 8, and 6, respectively. SFA, saturated fatty acid; UFA, Unsaturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acids. SFA, including C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, and C24:0. UFA, including C16:1, C18:1n9c, C18:1n9t, C18:2n6c, C18:3n3, C20:1, C20:2, C20:3n6, and C20:4n6. MUFA, including C16:1, C18:1n9c, C18:1n9t, and C20:1. PUFA, including C18:2n6c, C18:3n3, C20:2, C20:3n6, and C20:4n6.

Table 6

Effects of probiotics or synbiotics addition in sows' diets on plasma biochemical parameters of offspring pigs

Item	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	<i>P</i> values
ALT (U/L)						
65-day-old	58.79	56.28	56.81	59.15	2.369	0.782
95-day-old	54.74 ^b	54.22 ^b	59.60 ^b	78.33 ^a	4.811	0.004
125-day-old	51.77	48.18	50.76	48.10	3.847	0.873
ALP (U/L)						
65-day-old	148.88	164.00	134.57	155.50	8.351	0.108
95-day-old	123.63	127.17	118.50	122.83	10.524	0.951
125-day-old	162.88 ^{ab}	197.50 ^a	142.83 ^b	123.00 ^b	13.740	0.010
α-AMS (U/L)						
65-day-old	2260.50 ^a	1851.40 ^b	1842.17 ^b	1852.33 ^b	76.887	0.001
95-day-old	2186.71	2074.40	2176.80	2271.60	80.523	0.405
125-day-old	2306.00 ^b	2783.00 ^a	2438.25 ^{ab}	2806.00 ^a	121.075	0.016
AST (U/L)						
65-day-old	59.75	56.40	73.71	53.83	6.181	0.129
95-day-old	73.30 ^a	53.80 ^{bc}	47.33 ^c	63.75 ^{ab}	3.606	<.0001
125-day-old	65.17 ^a	47.20 ^b	49.50 ^b	67.50 ^a	5.292	0.023
CHE (g/L)						
65-day-old	534.63 ^a	540.33 ^a	420.29 ^b	548.33 ^a	16.605	<.0001
95-day-old	516.25 ^a	542.83 ^a	427.60 ^b	457.71 ^b	15.986	<.0001
125-day-old	467.67	475.25	445.50	487.25	13.724	0.203
LDH (U/L)						
65-day-old	416.75 ^b	332.20 ^c	503.67 ^a	378.17 ^{bc}	18.040	<.0001
95-day-old	465.71 ^a	374.43 ^b	322.67 ^b	437.67 ^a	19.825	<.0001
125-day-old	475.57 ^a	383.25 ^b	383.29 ^b	411.25 ^{ab}	26.291	0.042
ALB (g/L)						
65-day-old	41.23 ^a	35.54 ^b	41.21 ^a	40.50 ^a	0.643	<.0001
95-day-old	40.45	39.46	40.58	40.48	0.657	0.596
125-day-old	43.86	44.53	45.18	43.93	0.915	0.677
AMM (μmol/L)						
65-day-old	167.93	159.24	203.50	189.87	14.293	0.137
95-day-old	265.37 ^a	236.36 ^a	171.86 ^b	229.62 ^a	17.090	0.005
125-day-old	332.90 ^a	128.30 ^d	198.58 ^c	269.55 ^b	21.299	<.0001
TP (g/L)						
65-day-old	65.00	66.62	65.13	67.52	0.765	0.078
95-day-old	73.68 ^{ab}	73.68 ^{ab}	74.63 ^a	70.82 ^b	0.939	0.043

125-day-old	72.76 ^a	68.90 ^b	73.78 ^a	73.10 ^a	0.833	0.002
UN (mmol/L)						
65-day-old	3.10	3.20	3.18	2.87	0.341	0.901
95-day-old	3.56 ^a	3.60 ^a	2.42 ^c	3.14 ^b	0.127	<.0001
125-day-old	3.47 ^{ab}	3.98 ^a	3.93 ^a	3.35 ^b	0.158	0.020
HDL-C (mmol/L)						
65-day-old	0.76 ^b	0.75 ^b	0.74 ^b	0.88 ^a	0.033	0.019
95-day-old	1.07	1.11	1.05	1.01	0.036	0.292
125-day-old	1.10 ^b	1.22 ^a	1.23 ^a	1.09 ^b	0.036	0.010
LDL-C (mmol/L)						
65-day-old	1.28 ^b	1.08 ^c	1.26 ^b	1.50 ^a	0.050	<.0001
95-day-old	1.57	1.64	1.66	1.60	0.084	0.860
125-day-old	1.53	1.26	1.53	1.43	0.073	0.052
TC (mmol/L)						
65-day-old	2.37 ^b	2.12 ^c	2.31 ^b	2.53 ^a	0.053	<.0001
95-day-old	2.68	2.90	2.85	2.83	0.073	0.199
125-day-old	2.78 ^{ab}	2.59 ^b	3.05 ^a	2.78 ^{ab}	0.082	0.004
TG (mmol/L)						
65-day-old	0.49	0.48	0.49	0.53	0.034	0.734
95-day-old	0.76 ^a	0.60 ^{ab}	0.63 ^{ab}	0.51 ^b	0.047	0.009
125-day-old	0.62 ^b	0.61 ^b	0.56 ^b	0.82 ^a	0.034	<.0001
GLU (mmol/L)						
65-day-old	5.30 ^a	5.12 ^{ab}	5.30 ^a	4.66 ^b	0.176	0.049
95-day-old	6.40 ^a	4.66 ^b	5.18 ^b	4.78 ^b	0.246	<.0001
125-day-old	4.48	4.92	4.66	4.80	0.161	0.261

Data are presented as means with pooled SEM. Values in the same row with different superscript letters were significantly different ($P < 0.05$) The replicates per group at 65- and 95-day-old were 8. At 125-day-old, the replicates of the control group, antibiotic group, probiotics group, and synbiotics group are 8, 6, 8, and 6, respectively.

ALT, alanine aminotransferase; ALP, alkaline phosphatase; α -AMS, α -amylase; AST, aspartate aminotransferase; CHE, cholinesterase; LDH, lactate dehydrogenase; ALB, albumin; AMM, ammonia; TP, total protein; UN, urea nitrogen; HDL-C, high density lipoprotein-cholesterol; LDL-C, low density lipoprotein-cholesterol; TC, total cholesterol; TG, triglyceride; GLU, glucose.

Table 7

Effects of probiotics or synbiotics addition in sows' diets on plasma free amino acid of offspring pigs (nmol/mL)

Item	Control group	Antibiotic group	Probiotics group	Synbiotics group	SEM	<i>P</i> values
1-Mehis						
65-day-old	0.85	0.95	0.50	0.90	0.147	0.157
95-day-old	6.13 ^b	8.96 ^a	5.06 ^b	6.70 ^b	0.626	0.001
125-day-old	0.93	0.89	0.44	1.16	0.201	0.095
3-Mehis						
65-day-old	12.38	11.64	11.69	12.13	0.766	0.885
95-day-old	14.09	13.74	12.71	15.27	0.730	0.123
125-day-old	13.92	15.41	17.17	16.37	1.082	0.146
Ala						
65-day-old	419.55 ^a	445.57 ^a	323.57 ^b	391.40 ^{ab}	24.723	0.011
95-day-old	358.50 ^a	252.02 ^b	296.22 ^{ab}	347.86 ^a	18.048	0.001
125-day-old	312.99 ^b	393.20 ^a	301.66 ^b	284.56 ^b	20.815	0.009
Ans						
65-day-old	1.05	1.04	0.98	0.88	0.105	0.682
95-day-old	0.48 ^a	0.46 ^a	0.51 ^a	0.36 ^b	0.028	0.005
125-day-old	22.53 ^c	55.86 ^a	35.01 ^b	21.56 ^c	2.124	<.0001
Arg						
65-day-old	70.36	79.78	83.70	88.64	4.783	0.070
95-day-old	89.22 ^{ab}	67.25 ^b	69.73 ^b	102.12 ^a	6.953	0.004
125-day-old	84.84 ^b	105.52 ^a	85.15 ^b	88.29 ^b	3.540	0.001
Asp						
65-day-old	7.88	9.41	8.84	7.39	1.256	0.665
95-day-old	9.86	10.99	11.55	9.53	0.748	0.211
125-day-old	10.85 ^a	12.44 ^a	6.99 ^b	10.34 ^a	0.679	<.0001
Car						
65-day-old	10.51	10.61	10.72	7.03	1.152	0.087
95-day-old	10.93 ^a	8.97 ^a	3.30 ^b	8.24 ^a	0.985	<.0001
125-day-old	18.25	17.06	13.97	15.10	1.300	0.083
Cit						
65-day-old	25.65 ^c	30.35 ^b	23.54 ^c	34.81 ^a	1.272	<.0001
95-day-old	40.77 ^a	31.80 ^b	30.24 ^b	34.47 ^b	1.829	0.002
125-day-old	38.50	34.22	40.66	34.89	2.474	0.229
Cysthi						
65-day-old	13.04 ^b	7.55 ^c	13.52 ^b	18.79 ^a	0.927	<.0001
95-day-old	6.05 ^b	6.69 ^b	7.17 ^{ab}	8.37 ^a	0.437	0.006

125-day-old	9.97 ^b	9.13 ^b	10.88 ^{ab}	13.89 ^a	1.027	0.036
Cys						
65-day-old	9.56	11.19	8.58	12.69	1.062	0.052
95-day-old	94.43	93.56	59.16	70.89	14.719	0.264
125-day-old	12.55	11.11	7.17	12.87	1.872	0.115
EOHNH2						
65-day-old	0.27	0.31	0.25	0.28	0.031	0.558
95-day-old	24.52 ^b	36.69 ^a	0.46 ^c	0.27 ^c	2.086	<.0001
125-day-old	5.09 ^a	5.31 ^a	5.90 ^a	2.95 ^b	0.522	0.006
Glu						
65-day-old	186.00	211.73	197.39	183.61	11.824	0.334
95-day-old	207.52	175.66	213.62	215.32	11.319	0.066
125-day-old	155.75 ^a	133.41 ^b	159.41 ^a	134.23 ^b	4.571	<.0001
Gly						
65-day-old	525.00 ^a	441.15 ^b	417.84 ^b	517.45 ^a	22.405	0.003
95-day-old	470.34	472.11	484.09	560.27	29.847	0.129
125-day-old	566.31 ^b	744.00 ^a	517.49 ^b	582.66 ^b	20.194	<.0001
His						
65-day-old	36.13 ^{bc}	38.06 ^{ab}	39.58 ^a	35.05 ^c	0.834	0.003
95-day-old	43.72 ^a	38.14 ^b	37.98 ^b	40.04 ^{ab}	1.406	0.026
125-day-old	44.72 ^a	47.79 ^a	39.29 ^b	44.59 ^a	1.074	<.0001
Hylys						
65-day-old	1.08 ^b	0.99 ^b	1.77 ^a	1.00 ^b	0.144	0.001
95-day-old	0.55 ^b	0.21 ^b	0.31 ^b	17.46 ^a	0.545	<.0001
125-day-old	20.27	17.00	16.29	13.96	2.598	0.404
Hypro						
65-day-old	80.45 ^a	63.26 ^b	67.49 ^b	63.80 ^b	3.157	0.002
95-day-old	37.70	27.34	31.12	40.87	3.707	0.062
125-day-old	67.51	73.25	61.61	56.72	4.385	0.098
Ile						
65-day-old	100.01 ^a	89.39 ^b	85.87 ^b	106.56 ^a	3.376	0.001
95-day-old	90.11 ^a	72.10 ^b	68.44 ^b	75.76 ^b	3.811	0.002
125-day-old	86.29 ^b	98.37 ^{ab}	95.59 ^{ab}	101.40 ^a	3.731	0.042
Leu						
65-day-old	164.89 ^a	150.55 ^{ab}	141.18 ^b	157.55 ^{ab}	4.946	0.015
95-day-old	140.61 ^a	110.86 ^b	108.49 ^b	101.71 ^b	6.546	0.001
125-day-old	142.49 ^c	164.70 ^b	145.71 ^c	188.21 ^a	5.000	<.0001
Lys						
65-day-old	143.17	132.49	136.97	143.94	6.986	0.619
95-day-old	125.61	124.84	107.98	137.62	9.034	0.167

125-day-old	135.46 ^{bc}	152.98 ^a	124.49 ^c	146.49 ^{ab}	4.722	0.001
Met						
65-day-old	15.68	15.23	14.20	14.48	0.603	0.306
95-day-old	12.76	10.83	10.76	11.79	0.641	0.113
125-day-old	12.73 ^c	16.16 ^a	14.10 ^b	12.84 ^c	0.305	<.0001
Orn						
65-day-old	51.91	55.78	59.34	56.87	3.443	0.500
95-day-old	56.21 ^b	40.61 ^a	53.07 ^b	64.72 ^b	4.032	0.002
125-day-old	68.98 ^a	55.47 ^b	43.97 ^b	56.39 ^b	3.736	<.0001
Phe						
65-day-old	81.15	85.83	78.38	79.57	3.381	0.436
95-day-old	81.64	79.95	73.05	83.18	2.810	0.077
125-day-old	90.72 ^{ab}	92.96 ^a	85.38 ^b	88.08 ^{ab}	1.540	0.009
Pro						
65-day-old	173.12 ^b	214.35 ^a	163.76 ^b	188.85 ^b	7.593	<.0001
95-day-old	157.10	143.26	154.65	148.96	8.298	0.650
125-day-old	183.79 ^b	224.84 ^a	162.65 ^b	160.26 ^b	11.179	0.002
Sar						
65-day-old	8.53 ^a	3.72 ^b	4.13 ^b	6.10 ^{ab}	0.875	0.002
95-day-old	0.41 ^c	0.66 ^c	6.67 ^a	2.08 ^b	0.381	<.0001
125-day-old	2.25	2.38	2.28	2.28	0.115	0.855
Ser						
65-day-old	75.51	87.29	82.69	80.79	3.228	0.101
95-day-old	81.57	75.69	78.11	75.35	2.589	0.318
125-day-old	81.30 ^b	97.57 ^a	69.65 ^c	73.61 ^c	1.802	<.0001
Tau						
65-day-old	133.56 ^a	108.96 ^{bc}	100.33 ^c	121.25 ^{ab}	5.264	0.001
95-day-old	138.40 ^a	116.37 ^b	116.01 ^b	116.55 ^b	5.698	0.022
125-day-old	137.88 ^b	153.35 ^a	133.68 ^b	128.73 ^b	5.074	0.021
Thr						
65-day-old	116.70 ^b	151.48 ^a	108.88 ^b	117.32 ^b	7.145	0.001
95-day-old	105.91	107.08	113.80	114.86	8.913	0.852
125-day-old	119.87 ^b	147.49 ^a	111.62 ^b	113.26 ^b	4.004	<.0001
Tyr						
65-day-old	50.03 ^a	47.53 ^a	24.34 ^b	47.37 ^a	4.762	0.002
95-day-old	44.93	53.06	48.90	52.60	2.562	0.112
125-day-old	62.07 ^b	67.95 ^a	60.31 ^b	60.48 ^b	1.552	0.008
Val						
65-day-old	249.16 ^{ab}	222.48 ^b	220.34 ^b	264.19 ^a	12.257	0.047
95-day-old	213.22	183.85	205.35	209.81	8.517	0.089

125-day-old	237.37 ^b	283.85 ^a	257.01 ^{ab}	284.97 ^a	13.022	0.044
α -AAA						
65-day-old	65.81	56.64	67.93	57.40	4.768	0.247
95-day-old	60.05 ^a	45.61 ^b	47.63 ^b	45.07 ^b	2.733	0.002
125-day-old	55.04 ^{ab}	49.07 ^{ab}	57.68 ^a	44.23 ^b	3.369	0.049
α -ABA						
65-day-old	15.47 ^b	24.10 ^a	15.68 ^b	18.36 ^{ab}	2.277	0.042
95-day-old	12.16 ^a	4.47 ^b	0.66 ^c	4.87 ^b	1.147	<.0001
125-day-old	2.68 ^c	3.45 ^b	3.70 ^{ab}	4.06 ^a	0.131	<.0001
β -Ala						
65-day-old	8.33	5.87	6.00	7.30	0.763	0.096
95-day-old	8.88 ^a	3.91 ^c	2.70 ^c	6.33 ^b	0.555	<.0001
125-day-old	6.91 ^b	8.60 ^a	6.97 ^b	7.85 ^{ab}	0.273	<.0001
β -AiBA						
65-day-old	0.52 ^b	1.43 ^a	0.33 ^b	1.35 ^a	0.084	<.0001
95-day-old	0.66 ^c	2.55 ^a	1.72 ^b	1.73 ^b	0.196	<.0001
125-day-old	0.61 ^b	1.05 ^a	0.59 ^b	0.37 ^c	0.054	<.0001
γ -ABA						
65-day-old	0.25 ^b	0.21 ^b	0.16 ^b	0.59 ^a	0.041	<.0001
95-day-old	0.67 ^a	0.23 ^b	0.18 ^b	0.16 ^b	0.060	<.0001
125-day-old	1.81	1.89	1.66	1.64	0.115	0.374

Data are presented as means with pooled SEM. Values in the same row with different superscript letters were significantly different ($P < 0.05$) The replicates per group at 65- and 95-day-old were 8. At 125-day-old, the replicates of the control group, antibiotic group, probiotics group, and synbiotics group are 8, 6, 8, and 6, respectively.

1-Mehis, 1-methyl-histidine; 3-Mehis, 3-methyl-histidine; Ala, alanine; Ans, anserine; Arg, arginine; Asp, aspartate; Car, carnosine; Cit, citrulline; Cysthi, cystathionine; Cys, cysteine; EOHNH₂, ethanolamine; Glu, glutamate; Gly, glycine; His, histidine; Hylys, hydroxy-lysine; Hypro, hydroxy-proline; Ile, isoleucine; Leu, leucine; Lys, lysine; Met, methionine; Orn, ornithine; Phe, phenylalanine; Pro, proline; Sar, sarcosine; Ser, serine; Tau, taurine; Thr, threonine; Tyr, tyrosine; Val, valine; α -AAA, α -aminoadipic acid; α -ABA, α -amino-n-butyric acid; β -Ala, β -alanine; β -AiBA, β -aminoisobutyric acid; and γ -ABA, γ -amino-n-butyric acid.

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