Effects of Taurine on Growth Performance and Intestinal Health in Early-Weaned Piglets (Post-print)

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Abstract

This experiment aimed to investigate the effects of taurine (Tau) on growth performance, serum indices, intestinal mucosal morphology, and related gene expression in early-weaned piglets, as well as to compare the supplementation effects of Tau and glutamine (Gln). Thirty healthy early-weaned "(Landrace × Large Yorkshire) × Rongchang" piglets weaned at (17±2) days of age with an average body weight of (5.17±0.04) kg were selected and randomly divided into 3 groups with 10 replicates per group and 1 piglet per replicate. The control group (CON group) was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 0.1% Tau (T group) and 1.0% Gln (G group), respectively. The experimental period lasted 17 days, including a 3-day pre-trial period. The results showed that: 1) Compared with the control group, dietary supplementation of Tau and Gln significantly increased the average daily gain and average daily feed intake of early-weaned piglets ($P<0.05$), and decreased the diarrhea rate, with Gln being more effective than Tau. 2) The serum albumin (ALB) content in early-weaned piglets of the T group was significantly higher than that in the control and G groups ($P<0.05$); compared with the control group, the serum alkaline phosphatase (AKP) activity in the T and G groups was significantly increased ($P<0.05$), while the serum aspartate aminotransferase (AST) activity was significantly decreased ($P<0.05$). 3) Compared with the control group, the serum triglyceride (TG) content in early-weaned piglets of the T and G groups was significantly decreased ($P<0.05$). 4) The serum superoxide dismutase (SOD) activity in early-weaned piglets of the T group was significantly higher than that in the control and G groups ($P<0.05$); the serum catalase (CAT) activity in the T and G groups was significantly higher than that in the control group ($P<0.05$), with the G group showing better effects. 5) Compared with the control group, the serum essential amino acid (EAA) content in early-weaned piglets of the T and G groups showed an increasing trend, while the serum non-essential amino acid (NEAA) content showed a

decreasing trend, except for tryptophan (Try), histidine (His), isoleucine (Ile), phenylalanine (Phe), valine (Val), and glutamic acid (Glu); among these, dietary Tau supplementation was significantly more effective than Gln in increasing serum lysine (Lys), methionine (Met), and arginine (Arg) contents. 6) The jejunal villus height and villus height/crypt depth ratio in early-weaned piglets of the T and G groups were significantly higher than those in the control group (P<0.05), while the crypt depth was significantly lower than that in the control group (P<0.05). 7) The relative mRNA expression level of -catenin in the jejunal and ileal mucosa of early-weaned piglets in the T and G groups was significantly lower than that in the control group (P<0.05), with the G group being the lowest. The results of this experiment indicate that dietary supplementation with 0.1% Tau or 1.0% Gln can improve the growth performance and promote intestinal development of early-weaned piglets, with 1.0% Gln supplementation being slightly more effective than 0.1% Tau.

Full Text

Effects of Taurine on Growth Performance and Intestinal Health of Early-Weaned Piglets

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Abstract: This study investigated the effects and mechanisms of taurine (Tau) on growth performance, serum indices, intestinal mucosal morphology, and related gene expression in early-weaned piglets, and compared the supplemental effects of Tau and glutamine (Gln). Thirty healthy "(Landrace × Yorkshire) × Rongchang" early-weaned piglets weaned at (17±2) days of age with an average body weight of (5.17±0.04) kg were randomly allocated to 3 groups with 10 replicates per group and 1 piglet per replicate. The control group (CON) was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 0.1% Tau (T group) or 1.0% Gln (G group). The experiment lasted 17 days, including a 3-day adaptation period. The results showed that: 1) Compared with the CON group, dietary Tau and Gln significantly increased average daily gain and average daily feed intake (P<0.05), and decreased diarrhea rate, with Gln showing better effects than Tau. 2) Serum albumin (ALB) content in the T group was significantly higher than in the CON and G groups (P<0.05). Serum alkaline phosphatase (AKP) activity was significantly increased (P<0.05), while aspartate aminotransferase (AST) activity was significantly decreased (P<0.05) in both T and G groups compared with the CON group. 3) Serum triglyceride (TG) content was significantly lower in T and G groups than in the CON group (P<0.05). 4) Serum superoxide dismutase (SOD) activity in the T group was significantly higher than in the CON and G groups (P<0.05), while serum catalase (CAT) activity was significantly higher in both T and G groups than in the CON group (P<0.05), with the G group showing better effects. 5) Com-

pared with the CON group, serum essential amino acid (EAA) contents showed an increasing trend while non-essential amino acid (NEAA) contents showed a decreasing trend in T and G groups, except for tryptophan (Try), histidine (His), isoleucine (Ile), phenylalanine (Phe), valine (Val), and glutamate (Glu). Dietary Tau was more effective than Gln in increasing serum lysine (Lys), methionine (Met), and arginine (Arg) contents. 6) Jejunal villus height and villus height/crypt depth ratio were significantly higher ($P<0.05$), while crypt depth was significantly lower ($P<0.05$) in T and G groups compared with the CON group. 7) The mRNA relative expression level of -catenin in jejunal and ileal mucosa was significantly lower in T and G groups than in the CON group ($P<0.05$), with the lowest expression in the G group. These results indicate that dietary supplementation with 0.1% Tau or 1.0% Gln can improve growth performance and intestinal development in early-weaned piglets, with 1.0% Gln being slightly more effective than 0.1% Tau.

Key words: taurine; glutamine; early-weaned piglets; growth performance; intestinal development

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Piglet production is the most critical link in pig production and an important factor affecting the profitability of pig farming. In recent years, with the widespread application of early weaning technology, the requirements for piglet feeding and management have become increasingly demanding. Since many physiological functions of piglets are not yet mature, the growth performance of early-weaned piglets is limited, often manifesting as a series of adverse symptoms including anorexia or feed refusal, digestive disorders, diarrhea and edema, low feed utilization efficiency, and growth retardation, collectively known as "early weaning syndrome," which seriously affects the pig industry [1]. Glutamine (Gln), as a conditionally essential amino acid for weaned piglets, can effectively alleviate weaning stress, but its high cost and large required dosage substantially increase production expenses [2]. Taurine (Tau), as an abundant free amino acid (FAA), possesses antioxidant, lipid metabolism-regulating, cell-protective, immune-enhancing, and intestinal development-promoting functions. Due to its low cost and small required dosage, Tau has been applied in cat and poultry diets [3]. Therefore, this experiment supplemented Tau and Gln in weaned piglet diets to investigate the effects and mechanisms of Tau on growth performance and intestinal health, and to compare the supplemental effects of Tau and Gln, thereby providing a theoretical basis for further application of Tau in early-weaned piglet production.

1.1 Experimental Materials

Tau and Gln were purchased from Shanghai Yuanju Biotechnology Co., Ltd. Tau (A3820) was pharmaceutical grade with 99.0% purity, and Gln (A0090) had >98.5% purity. Assay kits for serum calcium (Ca2+), phosphorus (P), total protein (TP), albumin (ALB), total cholesterol (TC), triglycerides (TG), mal-

ondialdehyde (MDA), nitric oxide (NO), catalase (CAT), alkaline phosphatase (AKP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), nitric oxide synthase (NOS), anti-superoxide anion (ASA), lactate dehydrogenase (LDH), superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and total antioxidant capacity (T-AOC) were purchased from Nanjing Jiancheng Bioengineering Institute. Reverse transcription kits were purchased from Sangon Biotech Co., Ltd. Trizol, fluorescent quantitative PCR kits, and SYBR Green I were purchased from Invitrogen (USA).

1.2 Experimental Design and Basal Diet

The experiment was conducted at the Animal Feeding Base of the College of Animal Science and Technology, Southwest University. A single-factor completely randomized design was adopted. Thirty healthy Rongchang three-way crossbred "(Landrace × Yorkshire) × Rongchang" early-weaned piglets weaned at (17±2) days with an average body weight of (5.17±0.04) kg were randomly divided into 3 groups with 10 replicates per group and 1 piglet per replicate. The control group (CON) was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 0.1% Tau (T group) or 1.0% Gln (G group). Alanine was added at 1.2188% and 1.1476% to the CON and T groups, respectively, to maintain nitrogen balance. The composition and nutrient levels of the basal diet are shown in Table 1 .

The experimental period lasted 17 days, including a 3-day adaptation period. The experiment was conducted in a fully enclosed pig house that was disinfected before the trial. Piglets were individually housed and fed dry powder three times daily with ad libitum access to feed and water. Other management practices, deworming, and vaccination were performed according to routine farm procedures.

1.3 Sample Collection

Feed consumption and diarrhea incidence were recorded during the experiment. Body weight was measured at 06:00 before feeding on days 1 and 15 to calculate average daily gain (ADG), average daily feed intake (ADFI), feed/gain ratio (F/G), and diarrhea rate. On the morning of day 15, 5 piglets were randomly selected from each group for blood collection (10 mL from the anterior vena cava). Serum was harvested after standing for 1 hour and centrifuging at 3,000 r/min for 8 min at 4°C, then stored at -20°C for serum index and amino acid content determination. After blood collection, piglets were slaughtered to collect approximately 1 cm segments of mid-jejunum wall. After rinsing with 0.9% NaCl solution, samples were flattened on filter paper, trimmed, fixed in 10% formalin solution, paraffin-embedded, and sectioned for measurement of intestinal villus height and crypt depth. Jejunal and ileal mucosa were gently scraped with glass slides, frozen in liquid nitrogen, and stored at -80°C for determination of relative gene expression levels.

1.4.1 Growth Performance and Diarrhea Rate

Growth performance and diarrhea rate were calculated using the following formulas: - Average daily gain (g/d) = Total weight gain (g) / Experimental days (d) - Average daily feed intake (g/d) = Total feed intake (g) / Experimental days (d) - Feed/gain ratio = Feed consumption (g) / Weight gain (g) - Diarrhea rate (%) = 100 × Diarrhea incidents / (Number of piglets × Experimental days)

1.4.2 Serum Indices

Serum biochemical, lipid, and antioxidant indices were determined according to kit instructions. Serum amino acid samples were diluted 2-fold with 4% sulfosalicylic acid, centrifuged at 16,000 r/min for 2 min, filtered through a 0.22 m membrane, and analyzed using a Hitachi L-8800 automatic amino acid analyzer. Each sample analysis cycle was 53 min using two columns: a separation column (4.6 mm × 60 mm) with eluent flow rate of 0.4 mL/min at 70°C and 10.627 MPa pressure, and a reaction column with ninhydrin and ninhydrin buffer flow rate of 0.35 mL/min at 135°C and 0.982 MPa pressure.

1.4.3 Intestinal Mucosal Morphological Structure

Intestinal mucosal morphology was determined according to the method of Wang et al. [4]. Briefly, samples were removed from fixative, dehydrated in ethanol, cleared in xylene, paraffin-embedded, sectioned at 5 m thickness, stained with hematoxylin-eosin (HE), and observed under a microscope. Villus height and width were measured using OPTPro image processing software. Slides were read using a double-blind method, with 5 fields observed per section.

1.4.4 Relative mRNA Expression of Intestinal Mucosal -catenin and Regenerating Islet-Derived Protein-3 (Reg-3)

Total RNA was extracted from jejunal and ileal mucosa using Total RNA Extractor (Sangon Biotech Co., Ltd.). Samples with OD260 nm/OD280 nm ratios of 1.8–2.0 were used for subsequent experiments. Reverse transcription was performed using M-MLV First Strand cDNA Synthesis Kit (Sangon Biotech Co., Ltd.) to obtain cDNA. Primers were designed based on conserved regions of porcine glyceraldehyde-3-phosphate dehydrogenase (GAPDH), -catenin, and Reg-3 gene sequences from GenBank and synthesized by Sangon Biotech Co., Ltd. Primer sequences are shown in Table 2 .

The fluorescent quantitative PCR reaction system (25 L total volume) contained: 12 L Hotstart Fluo-PCR mix, 1 L each of forward and reverse primers (25 mol/L), 1 L cDNA, and 10 L ddH2O. Reaction conditions were: 94°C pre-denaturation for 4 min, followed by 35 cycles of 94°C denaturation for 30 s, 63°C annealing for 30 s, and 72°C extension for 30 s. Each sample was run in triplicate. Relative quantitative expression differences were calculated using the comparative Ct method, with target gene expression calculated as 2− Ct, where

Ct = (Ct_target gene − Ct_reference gene)_treatment − (Ct_target gene − Ct_reference gene)_control. The 2− Ct value represents the fold change of target gene expression in treatment groups relative to the control.

1.5 Data Processing and Statistics

Experimental data were organized using Excel 2003 and analyzed using SAS 9.0 software for one-way ANOVA. Significant differences were further analyzed using LSD multiple comparison tests. P<0.05 was considered statistically significant.

2.1 Growth Performance and Diarrhea Rate

As shown in Table 3 , compared with the CON group, dietary Tau and Gln reduced diarrhea rates by 26.08% and 39.14% during days 1-7, and by 29.65% and 51.84% during days 8-14, respectively, with Gln showing superior effects. Table 4 shows that initial body weight did not differ significantly among groups (P>0.05). Average daily gain and average daily feed intake were significantly higher in T and G groups than in the CON group (P<0.05). The G group showed 4.11% and 3.38% higher average daily gain and feed intake than the T group, respectively, though the differences were not significant (P>0.05). Feed/gain ratio was reduced by 13.00% in both T and G groups compared with the CON group, but the difference was not significant (P>0.05).

2.2 Serum Biochemical Indices

As shown in Table 5 , serum ALB content and AST and AKP activities differed significantly among groups (P<0.05). Specifically, serum ALB content in the T group was significantly higher than in the CON and G groups (P<0.05). Serum AST activity was significantly reduced by 7.51% and 11.17% in T and G groups, respectively, compared with the CON group (P<0.05), with the G group significantly lower than the T group (P<0.05). Serum AKP activity was significantly higher in both T and G groups than in the CON group (P<0.05), with no significant difference between T and G groups (P>0.05). Serum Ca2+ content in the T group was 24.89% and 14.12% higher than in the CON and G groups, respectively, but the differences were not significant (P>0.05). Serum P content was reduced by 17.85% and 12.50% in T and G groups compared with the CON group, but the differences were not significant (P>0.05).

2.3 Serum Lipid Indices

As shown in Figure 1 [Figure 1: see original paper], serum TC content did not differ significantly among groups (P>0.05). However, serum TG content was significantly lower in T and G groups than in the CON group (P<0.05), with no significant difference between T and G groups (P>0.05).

2.4 Serum Antioxidant Indices

As shown in Table 6 , serum SOD activity in the T group was significantly higher than in the CON and G groups (P<0.05), while no significant difference was observed between G and CON groups (P>0.05). Serum CAT activity was significantly higher in both T and G groups than in the CON group (P<0.05), with the best effect observed in the G group. Compared with the CON group, serum T-AOC was increased by 7.37% and 8.27%, NO content was reduced by 8.60% and 8.52%, and MDA content was reduced by 3.23% and 5.53% in T and G groups, respectively, though these differences were not significant (P>0.05).

2.5 Serum Amino Acid Content

As shown in Table 7 , compared with the CON group, serum essential amino acid (EAA) contents showed an increasing trend while non-essential amino acid (NEAA) contents showed a decreasing trend in T and G groups, except for tryptophan (Try), histidine (His), isoleucine (Ile), phenylalanine (Phe), valine (Val), and glutamate (Glu). Significant differences were observed among groups in serum Lys, Met, Arg, cysteine (Cys), leucine (Leu), threonine (Thr), alanine (Ala), aspartate (Asp), glycine (Gly), proline (Pro), and tyrosine (Tyr) contents (P<0.05). Dietary Tau was more effective than Gln in increasing serum Lys, Met, and Arg contents.

2.6 Intestinal Mucosal Morphological Structure

As shown in Table 8 , jejunal villus height and villus height/crypt depth ratio were significantly higher (P<0.05), while jejunal crypt depth was significantly lower (P<0.05) in T and G groups compared with the CON group, with no significant differences between T and G groups (P>0.05). Ileal villus height did not differ significantly among groups (P>0.05), but was increased by 6.19% and 6.58% in T and G groups compared with the CON group.

As shown in Figure 2 [Figure 2: see original paper], early weaning caused obvious shortening of jejunal and ileal villi, disordered physiological arrangement, severe breakage and large-area loss at villus tips, significantly reduced numbers, and even necrosis and erosion of some cells with increased lymphocyte infiltration. Compared with the CON group, T and G groups showed neatly arranged and dense jejunal and ileal villi with clear contours and significantly reduced broken fragments.

2.7 Relative mRNA Expression of -catenin and Reg-3 in Intestinal Mucosa

As shown in Figure 3 [Figure 3: see original paper], the mRNA relative expression level of -catenin in jejunal and ileal mucosa differed significantly among groups (P<0.05), with significantly lower expression in T and G groups than in the CON group (P<0.05) and the lowest expression observed in the G group.

No significant differences were observed among groups in Reg-3 mRNA relative expression levels in jejunal and ileal mucosa (P>0.05).

3.1 Effects of Tau on Growth Performance and Diarrhea Rate of Early-Weaned Piglets

Liu et al. [5] reported that dietary Tau supplementation improved growth rate and feed conversion ratio in weaned piglets. Huang et al. [6] found that adding 0.1% Tau to weaned piglet diets significantly improved growth performance in the first week, with average daily gain increasing by 6.63%, feed/gain ratio decreasing by 1.10%, and economic benefits increasing by 6.14%. Zhang et al. [7] observed that supplementing 1% Tau in weaned piglet diets reduced feed/gain ratio by 12.05% on day 10 post-weaning compared with the control group, with no significant differences in feed intake and daily gain but an improving trend; on day 20 post-weaning, daily gain increased by 27.75%. Li et al. [8] reported that dietary Gln supplementation tended to reduce diarrhea rate in weaned piglets. Liu [9] found that low-dose Tau supplementation significantly reduced diarrhea frequency in weaned piglets. The results of this study are consistent with these previous findings. The mechanisms by which Tau improves growth performance and reduces diarrhea rate may include: Tau can reduce gastrointestinal damage caused by weaning stress and enhance immune function and resistance; Tau promotes lipid metabolism in the body in the form of taurocholic acid and alleviates oxidative stress induced by weaning stress by clearing peroxides; Tau promotes the absorption of trace elements such as iron (Fe), copper (Cu), and zinc (Zn), thereby directly or indirectly promoting body development.

3.2 Effects of Tau on Serum Indices of Early-Weaned Piglets

This study showed that dietary Tau supplementation increased serum Ca2+ content in early-weaned piglets, which may be related to increased serum ALB content, as Ca2+ can bind to serum ALB. When intracellular Ca2+ content increases during stress, serum ALB acts as a Ca2+ carrier to transport Ca2+ out of cells and maintain cellular Ca2+ balance [10]. The results also showed that Tau significantly reduced serum AST activity, possibly by improving antioxidant function, reducing lipid peroxidation of cell membranes, protecting membrane integrity, and decreasing AST release from tissue cells [10]. Serum AKP in animals is produced by bone marrow and liver, and its content changes can reflect the physiological status of these organs and serve as an important indicator of animal health. This study found that serum AKP activity was significantly increased in T and G groups compared with the CON group, showing a roughly negative correlation with serum P content, consistent with the report by Liu [11]. This suggests that Tau can balance bone nutrition, inhibit osteoblast activity, achieve appropriate bone mineralization, and promote bone growth in weaned piglets. Chen et al. [12] reported that serum AKP activity decreases with animal age, possibly because AKP is a product of osteoblasts whose activity declines when osteoblasts become osteocytes.

This study investigated lipid metabolism in early-weaned piglets by analyzing TC and TG. No significant differences were observed in serum TC content among groups, while serum TG content was significantly lower in T and G groups than in the CON group, indicating that 0.1% Tau supplementation can regulate lipid metabolism to some extent, with effects comparable to 1.0% Gln. The mechanisms may involve: Tau can promote synthesis of 7 -hydroxylase, the rate-limiting enzyme in bile acid synthesis, thereby accelerating clearance of TC and TG; Tau can reduce TG content by upregulating low-density lipoprotein-cholesterol receptor (LDLR) expression or enhancing LDLR binding capacity. Zeng et al. [13] found that dietary Tau significantly increased lipase activity in pancreas and small intestinal contents of 21-day-old broilers. Gao et al. [14] reported that Tau affected lipid metabolism in fish by increasing lipase activity.

Although no significant differences were observed in serum GSH-Px activity among groups, dietary 0.1% Tau significantly increased serum SOD and CAT activities, with MDA content showing a decreasing trend. Winiarska et al. [15] showed that Tau increased SOD and GSH-Px activities in rabbit serum and liver, enhanced antioxidant capacity, and reduced serum MDA content. Wang et al. [16] reported that Tau reduced serum MDA content in laying quails, indicating its role in reducing lipid peroxidation and improving antioxidant capacity. Hao et al. [17] reviewed that Tau can reduce intracellular MDA and reactive oxygen species contents while increasing SOD and GSH-Px activities, consistent with our findings. This study also showed that Tau reduced serum NO content, possibly by inhibiting NOS gene expression. Roy et al. [18] reported that Tau can reduce NO content by blocking NOS gene expression through transcription factors, thereby inhibiting stress-induced inflammatory responses and protecting cells.

The results showed that Tau increased serum Lys, Met, Arg, Cys, and Leu contents, with significantly better effects on Lys, Met, and Arg than Gln. The increases in serum Leu and Lys may be related to increased serum ALB content, as ALB is an important protein synthesized in the liver and a key indicator of nutritional status, composed mainly of Leu and Lys. Increased ALB content is often accompanied by increased Leu and Lys contents [19]. This study also found that Tau increased serum ALB content in early-weaned piglets. Zheng et al. [20] reported that under oxidative stress, tissue metabolism requires more amino acids, enhancing tissue uptake of plasma EAAs and significantly reducing serum Met, Arg, and Cys contents in weaned piglets. In this study, the increased serum Met, Arg, and Cys contents may be due to Tau reducing oxidative stress and tissue uptake of serum EAAs, thereby increasing their serum concentrations. The results also showed that Tau significantly reduced serum Ala, Gly, and Pro contents. The decreases in Ala and Gly may be because weaning stress enhances tissue amino acid metabolism and EAA uptake, while Tau metabolism is unrelated to Ala and Gly [21]. Pro, as a metabolite of Arg, is affected by Arg synthesis; the significant increase in Arg content leads to decreased metabolite content and consequently reduced Pro content [22].

3.3 Effects of Tau on Intestinal Mucosal Morphology of Early-Weaned Piglets

This study found that dietary supplementation with 0.1% Tau or 1.0% Gln significantly increased jejunal villus height and villus height/crypt depth ratio, significantly decreased jejunal crypt depth, with no significant differences between Tau and Gln. Ileal villus height showed an increasing trend, and intestinal epithelial structure integrity was markedly higher in the T group than in the CON group, indicating that Tau can alleviate intestinal stress caused by early weaning. Wang [23] reported that Tau alleviated villus shedding and necrosis of small intestinal epithelial cells induced by inflammation, reduced inflammatory cell infiltration, and decreased NO and MDA contents while increasing SOD activity in plasma and intestinal tissue. It is speculated that Tau may protect intestinal mucosa by reducing intestinal oxidative stress, which may be associated with reduced diarrhea rate. Additionally, Tau may alleviate weaning stress by inhibiting intestinal endotoxin translocation and promoting expression of intestinal-related genes, thereby protecting intestinal integrity [24].

3.4 Effects of Tau on Intestinal Mucosal Gene Expression in Early-Weaned Piglets

The results showed that dietary Tau and Gln significantly reduced -catenin mRNA relative expression levels in jejunal and ileal mucosa. The reduction in -catenin expression may be related to Tau' s antioxidant capacity [25]. Studies have shown that Tau can increase antioxidant enzyme activities (SOD, CAT, GSH-Px) in rat serum and tissues, which can scavenge hydrogen peroxide (H2O2) [26]. Tian [27] found that -catenin mRNA expression was significantly increased in an H2O2-induced oxidative stress model of human fibroblasts, and that inhibiting the Wnt/ -catenin signaling pathway could reduce oxidative stress. It is speculated that Tau may affect Wnt/ -catenin signaling pathway activation by reducing intestinal H2O2 content, thereby decreasing -catenin release from complexes and reducing its mRNA expression. Tau can also reduce the immunosuppressive factor tumor necrosis factor- (TNF-) [17], and Tau supplementation can decrease blood TNF- content [28]. Fan [29] found that TNF- binds to cell membrane receptors, enters the cytoplasm, and maintains -catenin stability, preventing its degradation and allowing nuclear translocation to activate the Wnt/ -catenin signaling pathway. It is speculated that Tau may reduce intestinal TNF- content, thereby decreasing Wnt/ -catenin pathway activation and reducing -catenin mRNA expression.

Conclusions

1. Dietary supplementation with 0.1% Tau or 1.0% Gln significantly increased average daily gain, average daily feed intake, jejunal villus height, and villus height/crypt depth ratio, and significantly decreased feed/gain ratio in early-weaned piglets.

2. Dietary supplementation with 0.1% Tau or 1.0% Gln increased serum Ca2+ and EAA contents and AKP, SOD, and CAT activities, and significantly reduced serum TG content and intestinal mucosal -catenin mRNA relative expression levels.

3. Dietary supplementation with 0.1% Tau or 1.0% Gln can improve growth performance and promote intestinal development in early-weaned piglets, with 1.0% Gln being slightly more effective than 0.1% Tau.

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