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饲粮添加益生菌和合生元对环江香猪生长性能及血浆生化参数的影响

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摘　要: 本试验旨在研究饲粮添加益生菌和合生元对环江香猪生长性能和血浆生化参数的影响。选取窝产仔数相近的新生仔猪24窝,随机分为3组,每组8个重复。对照组饲喂基础饲粮,试验组分别在基础饲粮中添加0.05%丁酸梭菌(益生菌组)或0.05%丁酸梭菌+0.02%低聚木糖(合生元组)。仔猪10日龄之前随母猪哺乳;10~35日龄随母猪哺乳,同时补充教槽饲粮;36~65日龄饲喂保育前期饲粮。试验期间,记录每日采食量和腹泻情况,于10、35和65日龄称取空腹体重,计算各阶段平均日采食量(ADFI)、平均日增重(ADG)、料重比(F/G)和腹泻率;于35和65日龄采血,检测血浆生化参数。结果显示:与对照组相比,益生菌组和合生元组65日龄仔猪体重显著增加($P<0.05$),10~35日龄、36~65日龄和10~65日龄阶段仔猪腹泻率显著降低($P<0.05$),36~65日龄和10~65日龄阶段仔猪ADFI和ADG显著升高($P<0.05$),35日龄仔猪血浆总蛋白(TP)含量和碱性磷酸酶(ALP)活性显著升高且谷丙转氨酶(ALT)活性显著降低($P<0.05$),65日龄仔猪血浆TP、白蛋白(ALB)和甘油三酯(TG)含量以及ALP活性显著升高且ALT和谷草转氨酶(AST)活性显著降低($P<0.05$);此外,合生元组35日龄仔猪血浆低密度脂蛋白-胆固醇(LDL-C)含量、65日龄仔猪血浆总胆固醇(TC)和LDL-C含量显著升高($P<0.05$)。与益生菌组相比,合生元组36~65日龄和10~65日龄阶段仔猪ADFI和ADG显著升高($P<0.05$),10~35日龄、36~65日龄和10~65日龄阶段仔猪腹泻率显著降低($P<0.05$),35日龄仔猪血浆LDL-C含量、65日龄仔猪血浆LDL-C和TC含量以及ALP活性显著升高($P<0.05$)。综上所述,饲粮添加益生菌或合生元均可改善环江香猪氮代谢和脂代谢相关的血浆生化参数,降低腹泻率,进而提高生长性能。

关键词: 丁酸梭菌;合生元;环江香猪;生长性能;血浆生化参数

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早期断奶应激引起的仔猪生长缓慢、腹泻率和死亡率高等问题制约了养猪业的健康可持续发展[1]。通过营养调控手段改善仔猪肠道健康、提高其生长性能是解决上述问题的重要途径。有研究表明,益生菌、合生元等益生物质可改善动物的肠道健康,降低腹泻率,进而提高生长性能[2-3]。因此,研发益生菌、合生元等功能性饲料添加剂对保障仔猪健康具有重要意义。丁酸梭菌(*Clostridium butyricum*,CB)是一种重要的益生菌,对酸、胆酸盐和抗生素等的耐受性较强[4],其代谢产物丁

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酸可为肠上皮细胞的再生和修复提供能量[5]。饲粮添加 CB 可显著提高断奶仔猪的平均日采食量(ADFI)和平均日增重(ADG),显著降低腹泻率[6]。合生元是由益生菌和益生元组合而成的一种微生态制剂,由木寡糖和地衣芽孢杆菌[7]、益生菌和低聚木糖(XOS)[8]组成的合生元能够增强仔猪的肠道健康,提高其生长性能。本课题组前期研究发现,饲粮中添加一定剂量的 XOS 可增强仔猪的肠道健康,减少腹泻,并促进其生长[9];可增加仔猪肌肉中粗蛋白质、氨基酸和脂肪酸的含量[10];还可改善育肥猪的肉品质和营养价值[11]。但由 CB 和 XOS 组成的合生元对环江香猪的饲喂效果如何,尚未见报道。因此,本试验拟研究饲粮添加益生菌和合生元对环江香猪生长性能和血浆生化参数的影响,为其在环江香猪健康养殖中的应用提供依据。

1　材料与方法

1.1　试验材料

CB 活菌数≥1×10^9 CFU/g;XOS 主要成分为木二糖、木三糖和木四糖等,含量≥35%。

1.2　试验动物、分组与饲养管理

动物试验在广西壮族自治区环江毛南族自治县环江香猪原种保种场开展。试验选取生产时间和窝产仔数相近的新生仔猪 24 窝,随机分为 3 组,每组 8 个重复。对照组饲喂基础饲粮,试验组分别在基础饲粮中添加 0.05% CB(益生菌组)和 0.05% CB+0.02% XOS(合生元组),添加剂量根据前人研究结果[6,9]以及产品推荐剂量确定。仔猪 10 日龄前随母猪哺乳;10~35 日龄随母猪哺乳,同时补充教槽饲粮;36~65 日龄饲喂保育前期饲粮。

基础饲粮的常规营养水平参照《猪饲养标准》(NY/T 65—2004)、预混料参考 NRC(2012)仔猪营养需求标准配制,其组成及营养水平见表 1。每天喂料 3 次,自由采食和饮水。其他饲养管理与免疫程序按猪场常规饲养管理方法进行。

1.3　生长性能测定

试验期间记录每窝仔猪每日的采食量,分别于 10、35 和 65 日龄称取空腹体重,计算 ADFI、ADG 和料重比(F/G)。试验期间记录每窝仔猪每天的腹泻情况,计算腹泻率。

表 1　基础饲粮组成及营养水平(风干基础)

Table 1　Composition and nutrient levels of basal diets (air-dry basis)　%

项目 Items	教槽饲粮 Creep diet	保育前期饲粮 Early nursery diet
原料 Ingredients		
玉米 Corn	56.75	55.00
豆粕 Soybean meal	22.25	22.00
鱼粉 Fish meal	3.00	
麦麸 Wheat bran	8.00	10.63
米糠 Rice bran	6.00	8.37
预混料 Premix[1)]	4.00	4.00
合计 Total	100.00	100.00
营养水平 Nutrient levels[2)]		
消化能 DE/(MJ/kg)	13.70	13.42
粗蛋白质 CP	17.61	16.05
钙 Ca	0.23	0.70
总磷 TP	0.45	0.38
赖氨酸 Lys	0.78	0.68
蛋氨酸+半胱氨酸 Met+Cys	0.53	0.49
苏氨酸 Thr	0.54	0.48

1)预混料为每千克饲粮提供 Premix provided the following per kilogram of diets: VA 4 000 IU, VD_3 1 200 IU, VE 40 IU, VK_3 0.8 mg, VB_1 1.6 mg, VB_2 1.6 mg, VB_6 1.2 mg, VB_{12} 0.016 mg, 生物素 biotin 0.08 mg, 泛酸 pantothenic acid 6 mg, 烟酸 niacin 14 mg, 氯化胆碱 choline chloride 300 mg, Cu (as copper sulfate) 127 mg, Fe (as ferrous sulfate) 171.6 mg, Zn (as zinc sulfate) 116 mg, Mn (as manganese sulfate) 43 mg, K (as potassium iodide) 0.34 mg, I (as potassium iodide) 0.26 mg, Co (as cobalt chloride) 0.14 mg, Se (as sodium selenite) 0.16 mg。

2)营养水平均为计算值。Nutrient levels were calculated values.

1.4　血浆生化参数测定

分别于 35 和 65 日龄随机从每窝选取接近平均体重的仔猪 1 头,前腔静脉采血 10 mL,肝素抗凝,3 000 r/min 离心 15 min,分离血浆。用 Cobras c311 型全自动生化分析仪测定血浆中谷草转氨酶(AST)、谷丙转氨酶(ALT)和碱性磷酸酶(ALP)的活性以及总蛋白(TP)、白蛋白(ALB)、氨(NH_3)、尿素氮(UN)、总胆固醇(TC)、甘油三酯(TG)、低密度脂蛋白-胆固醇(LDL-C)和高密度脂蛋白-胆固醇(HDL-C)的含量,按照试剂盒(北京利德曼公司提供)说明书进行操作。

1.5 数据统计与分析

试验数据采用 SPSS 22.0 软件进行单因素方差分析(one-way ANOVA),并采用 Duncan 氏法进行组间多重比较,以“平均值±标准差”表示。$P<0.05$ 表示差异显著。

2 结果与分析

2.1 饲粮添加益生菌和合生元对环江香猪生长性能和腹泻率的影响

由表 2 可知,与对照组相比,益生菌组和合生元组 10~35 日龄阶段仔猪的腹泻率显著降低($P<0.05$),36~65 日龄和 10~65 日龄阶段仔猪的 ADFI和 ADG 显著增加且腹泻率显著降低($P<0.05$),65 日龄仔猪的体重显著增加($P<0.05$)。与益生菌组相比,合生元组 10~35 日龄、36~65 日龄和 10~65 日龄阶段仔猪的腹泻率显著降低($P<0.05$),36~65 日龄和 10~65 日龄阶段仔猪的 ADFI和 ADG 显著增加($P<0.05$)。

2.2 饲粮添加益生菌和合生元对环江香猪血浆生化参数的影响

由表 3 可知,与对照组相比,35 日龄时,益生菌组和合生元组血浆 TP 含量和 ALP 活性显著升高、ALP 活性显著降低($P<0.05$),合生元组血浆 LDL-C 含量显著升高($P<0.05$);65 日龄时,益生菌组和合生元组血浆 TP、ALB 和 TG 含量以及 ALP 活性显著升高($P<0.05$)、ALP 和 AST 活性显著降低($P<0.05$),合生元组血浆 TC 和 LDL-C 含量显著升高($P<0.05$)。另外,合生元组 35 日龄血浆 LDL-C 含量、65 日龄血浆 LDL-C 和 TC 含量以及 ALP 活性显著高于益生菌组($P<0.05$)。

表 2 饲粮添加益生菌和合生元对环江香猪生长性能和腹泻率的影响

Table 2 Effects of dietary supplementation with probiotics and synbiotics on growth performance and diarrhea rate of *Huanjiang* mini-piglets ($n=8$)

项目 Items	对照组 Control group	益生菌组 Probiotics group	合生元组 Synbiotics group
10 日龄体重 BW at 10 days of age/kg	1.45±0.06	1.45±0.06	1.44±0.06
65 日龄体重 BW at 65 days of age/kg	8.35±0.15^{b}	8.72±0.20^{a}	8.86±0.18^{a}
10~35 日龄 10 to 35 days of age			
平均日采食量 ADFI/g	36.8±3.4	37.1±2.9	36.8±3.9
平均日增重 ADG/g	108.1±9.6	112.3±11.7	112.2±11.5
料重比 F/G	0.34±0.04	0.33±0.03	0.33±0.04
腹泻率 Diarrhea rate/%	9.78±1.11^{a}	7.17±1.36^{b}	5.21±0.70^{c}
36~65 日龄 36 to 65 days of age			
平均日采食量 ADFI/g	480.2±11.9^{c}	493.9±7.0^{b}	506.7±2.9^{a}
平均日增重 ADG/g	140.8±8.2^{c}	151.1±11.6^{b}	160.6±5.8^{a}
料重比 F/G	3.42±0.21	3.29±0.27	3.16±0.10
腹泻率 Diarrhea rate/%	10.35±1.72^{a}	6.90±1.51^{b}	5.66±1.02^{c}
10~65 日龄 10 to 65 days of age			
平均日采食量 ADFI/g	253.4±6.7^{c}	260.9±6.3^{b}	268.1±7.8^{a}
平均日增重 ADG/g	120.5±3.0^{c}	127.6±4.0^{b}	132.2±4.6^{a}
料重比 F/G	2.10±0.09	2.05±0.06	2.03±0.05
腹泻率 Diarrhea rate/%	9.72±1.03^{a}	6.79±0.90^{b}	5.26±0.58^{c}

同行数据肩标不同字母表示差异显著($P<0.05$)。下表同。

In the same row, values with different letter superscripts mean significant difference ($P<0.05$). The same as below.

3 讨 论

现有研究表明,合生元可通过增加肠道内有益菌的相对丰度,提高微生物代谢产物短链脂肪酸(SCFA)的含量发挥益生作用,从而增加仔猪的 ADFI 和 ADG[12]。本研究发现,饲粮添加益生菌或合生元后,仔猪各阶段腹泻率均显著降低,断奶后的 ADFI 和 ADG 以及 65 日龄体重均显著增加,

表明饲粮添加益生菌或合生元可显著增强环江香猪的肠道健康,提高其生长性能。已有研究表明,饲粮添加 6×10^9 CFU/kg CB 可显著增加断奶仔猪的 ADFI、ADG 和末重,显著降低腹泻率和 F/G[13];饲粮添加由 XOS 和益生菌组成的合生元制剂可显著降低仔猪黄白痢的发生率[8]。益生菌和合生元可能通过以下途径发挥作用:1)CB 能产生酶、维生素、脂肪酸和丁酸梭菌素等物质,从而发挥促生长、提高饲料转化率和维持肠道健康等功能[14];2)XOS 能促进双歧杆菌和乳酸菌的增殖,进而抑制有害菌在肠上皮细胞上的黏附[15];3)CB 能促进双歧杆菌、乳酸菌和粪杆菌等有益菌的繁殖[11]。另外,本研究还发现,合生元较益生菌的效果更好,表明 CB 和 XOS 可产生协同效应,这与邓文等[16]的报道一致。不过,合生元的促生长效果优于益生菌的具体机制还有待进一步研究。

表 3　饲粮添加益生菌和合生元对环江香猪血浆生化参数的影响

Table 3　Effects of dietary supplementation with probiotics and synbiotics on plasma biochemical parameters of *Huanjiang* mini-piglets ($n=8$)

项目 Items	日龄 Days of age	对照组 Control group	益生菌组 Probiotics group	合生元组 Synbiotics group
总蛋白 TP/(g/L)	35	53.71±3.77^b	58.36±5.04^a	59.96±3.22^a
	65	62.74±3.03^b	70.43±5.98^a	71.58±2.83^a
白蛋白 ALB/(g/L)	35	30.66±1.80	28.63±4.70	27.14±5.95
	65	32.61±3.42^b	36.85±3.01^a	37.11±2.97^a
氨 NH_3/(μmol/L)	35	259.93±40.09	251.36±37.60	248.58±41.01
	65	282.06±42.41	276.75±36.33	271.35±45.83
尿素氮 UN/(mmol/L)	35	2.91±0.88	2.50±0.41	2.95±1.41
	65	4.54±1.37	4.01±0.80	3.79±1.28
甘油三酯 TG/(mmol/L)	35	0.67±0.16	0.66±0.19	0.66±0.15
	65	0.39±0.09^b	0.63±0.23^a	0.80±0.21^a
总胆固醇 TC/(mmol/L)	35	2.28±0.27	2.36±0.23	2.37±0.24
	65	2.06±0.27^b	2.24±0.31^b	2.87±0.31^a
高密度脂蛋白-胆固醇 HDL-C/(mmol/L)	35	0.73±0.29	0.59±0.17	0.73±0.27
	65	0.56±0.14	0.54±0.14	0.62±0.15
低密度脂蛋白-胆固醇 LDL-C/(mmol/L)	35	1.03±0.11^b	1.01±0.11^b	1.19±0.07^a
	65	1.13±0.20^b	1.28±0.19^b	1.71±0.22^a
碱性磷酸酶 ALP/(U/L)	35	127.13±22.52^b	157.75±16.46^a	178.38±23.44^a
	65	127.00±12.97^c	151.75±11.77^b	188.25±6.43^a
谷丙转氨酶 ALT/(U/L)	35	34.81±4.37^a	26.62±10.73^b	22.40±7.96^b
	65	37.99±7.88^a	24.62±5.80^b	20.50±6.09^b
谷草转氨酶 AST/(U/L)	35	34.25±4.50	32.13±5.22	35.75±5.06
	65	55.75±8.48^a	44.13±9.79^b	40.25±8.26^b

血浆 TP、ALB、UN 和 NH_3 含量是衡量机体氮代谢的主要指标。血浆 TP 和 ALB 含量可反映机体对蛋白质的吸收和代谢水平,ALB 含量与动物的生长速度呈正相关[17]。本研究中,饲粮添加益生菌或合生元后,35 日龄时血浆 TP 含量以及 65 日龄时血浆 TP 和 ALB 含量均显著升高,提示此阶段仔猪对蛋白质的消化能力增强。AST 和 ALT 是动物机体内重要的转氨酶,其活性是反映肝脏和心脏功能的重要指标,可影响多种氨基酸的代谢[18]。本研究中,饲粮添加益生菌或合生元后,35 日龄时血浆 ALT 活性和 65 日龄时血浆 ALT 和 AST 活性均显著降低,表明环江香猪心脏和肝脏功能正常,机体对氨基酸的利用率提高,这与 Wang 等[13]的报道一致。血液中的 ALP 主要来源于肝脏和骨骼。在临床上,ALP 主要用于肝脏疾病的诊断。患病时肝细胞过度生成 ALP,经淋巴

管和肝窦进入血液,同时由于肝内胆管胆汁排泄障碍,反流入血而引起血液 ALP 活性明显升高[19]。ALP 作为消化代谢的关键酶,还能促进磷酸钙在骨骼内的蓄积,是反映骨生成状况和钙、磷代谢的重要指标[20]。本研究中,饲粮添加益生菌或合生元后,35 和 65 日龄时血浆 ALP 活性显著升高。这可促进机体对钙、磷的吸收,增强骨骼钙化,从而有利于此阶段仔猪的骨骼发育。

血浆 TC、TG、HDL-C 和 LDL-C 含量是衡量机体脂类代谢强弱的重要指标。血浆 TG 和 TC 含量可反映机体对脂肪代谢的强弱,脂肪组织发育和脂肪沉积取决于血浆 TG 含量,血浆 TG 含量降低提示脂肪沉积可能下降[21];HDL-C 和 LDL-C 是运输胆固醇的载体,LDL-C 将肝脏合成的胆固醇转运至肝外组织,而 HDL-C 则把胆固醇运回肝脏代谢转化为其他物质,从而维持机体内脂类代谢的稳定[22]。本试验中,饲粮添加益生菌显著提高了 65 日龄时血浆 TG 含量,饲粮添加合生元显著提高了 35 日龄时血浆 LDL-C 含量以及 65 日龄时血浆 TG、TC 和 LDL-C 含量,提示益生菌或合生元可在一定程度上增强环江香猪的脂代谢,提高机体的脂肪沉积能力。

4 结 论

饲粮添加益生菌或合生元均可改善环江香猪氮代谢和脂代谢相关的血浆生化参数,降低腹泻率,进而提高生长性能。

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Effects of Dietary Supplementation with Probiotics and Synbiotics on Growth Performance and Plasma Biochemical Parameters of *Huanjiang* Mini-Piglets

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Abstract: This experiment was conducted to study the effects of dietary supplementation with probiotics and synbiotics on growth performance and plasma biochemical parameters of *Huanjiang* mini-piglets. A total of 24 litters of newborn piglets with similar litter size were randomly divided into three groups with eight replicates per group. The piglets in control group were fed a basal diet, and the piglets in experimental groups were fed the basal diet supplemented with 0.05% *Clostridium butyricum* (CB, probiotics group) or 0.05% CB+0.02% xylo-oligosaccharides (synbiotics group), respectively. During 1 to 9 days of age, piglets took milk from their mother, during 10 to 35 days of age, piglets took milk from their mother and supplementary fed creep diet; during 36 to 65 days of age, piglets fed early nursery diet. During the experiment, feed intake and diarrhea were recorded daily; fasting body weight was measured at 10, 35 and 65 days of age; average daily feed intake (ADFI), average daily gain (ADG), feed/gain (F/G) and diarrhea rate were calculated at each stage; blood samples were collected at 35 and 65 days of age to determine plasma biochemical parameters. The results showed that, compared with the control group, the body weight at 65 days of age of piglets in the probiotics group and synbiotics group was significantly increased ($P<0.05$), the diarrhea rate was significantly decreased during 10 to 35 days of age, 36 to 65 days of age and 10 to 65 days of age ($P<0.05$), and the ADFI and ADG were significantly increased during 36 to 65 days of age and 10 to 65 days of age ($P<0.05$); at 35 days of age, the plasma total protein (TP) content and alkaline phosphatase (ALP) activity of probiotics group and symbiotics group were significantly increased ($P<0.05$), while the alanine transaminase (ALT) activity was significantly decreased ($P<0.05$); at 65 days of age, the plasma TP, albumin (ALB), triglyceride (TG) contents and ALP activity of probiotics group and synbiotics group were significantly increased ($P<0.05$), while the ALT and aspartate aminotransferase (AST) activities were significantly decreased ($P<0.05$); the low density lipoprotein-cholesterol (LDL-C) content of symbiotics group was significantly increased at 35 days of age ($P<0.05$), as well as the total cholesterol (TC) and LDL-C contents at 65 days of age. Compared with the probiotics group, the diarrhea rate was significantly decreased in the synbiotics group during 10 to 35 days of age, 36 to 65 days of age and 10 to 65 days of age ($P<0.05$); the ADFI and ADG were significantly increased in the synbiotics group during 36 to 65 days of age and 10 to 65 days of age ($P<0.05$); the plasma LDL-C content at 35 days of age was significantly increased in the synbiotics group ($P<0.05$), as well as plasma LDL-C and TC contents and ALP activity at 65 days of age. In summary, dietary supplementation with probiotics or synbiotics can increase the plasma biochemical parameters related with nitrogen metabolism and lipid metabolism, reduce the diarrhea rate, and then increase the growth performance of *Huanjiang* mini-piglets. [***Chinese Journal of Animal Nutrition*, 2021, 33(1): 546-552**]

Key words: *Clostridium butyricum*; synbiotics; *Huanjiang* mini-piglets; growth performance; plasma biochemical parameters

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