日粮中添加无机磷和植酸酶对肉鸡骨骼及生长性能的影响

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[摘 要] 【目的】研究不同无机磷水平日粮中添加植酸酶对肉鸡生长性能及骨骼的影响,以确定适宜的无机磷和植酸酶用量。【方法】选取 1 日龄肉鸡 1 500 只,随机分为 5 个处理,对照组日粮中添加 16.3 g/kg 磷酸氢钙,其余 4 组分别添加 12.3,8.2,4.1 和 0 g/kg 磷酸氢钙后再添加 500 FTU/kg 植酸酶,各组钙磷比为 1.2～1.4,测定各组鸡的生长性能、胫骨鲜重、胫骨脱脂重、胫骨灰分和矿物质元素含量以及胫骨折断强度。【结果】未添加磷酸氢钙组肉鸡的日平均采食量、日增重均显著低于对照组($P<0.05$);添加 8.2 g/kg 磷酸氢钙组肉鸡日增重最高,料重比最低;肉鸡胫骨鲜重、脱脂率在各处理间差异不显著($P>0.05$),脱脂率随日粮中添加无机磷水平的降低而升高;胫骨脱脂重随日粮中无机磷水平下降而降低,28 日龄未添加磷酸氢钙组肉鸡的胫骨脱脂重显著低于其他组($P<0.05$)。28 日龄肉鸡胫骨灰分含量以未添加磷酸氢钙组显著低于其他各组($P<0.05$);胫骨钙、磷含量以未添加磷酸氢钙组低于其他各组,但各组差异不显著($P>0.05$);28 日龄肉鸡胫骨镁、锰、铜、铁、锌含量随日粮中无机磷添加水平的降低而逐渐升高,42 日龄肉鸡胫骨镁、锰、铁含量在添加植酸酶组也有同样变化。肉鸡胫骨折断强度以未添加磷酸氢钙组低于其他各组,其中 28 日龄肉鸡该组胫骨折断强度显著低于其他组($P<0.05$)。【结论】日粮中添加植酸酶能提高肉鸡生长性能及矿物质元素的利用率,但不能完全替代磷酸氢钙,以添加 8.2 g/kg 磷酸氢钙组(0～4 周龄:Ca 7.6 g/kg,总磷(TP) 5.4 g/kg;5～7 周龄:Ca 7.0 g/kg,TP 5.3 g/kg)后再添加植酸酶对肉鸡的饲养效果较好,鉴于植酸酶对矿物元素的释放作用,有必要重新评定日粮配方中矿物元素的需要量。

[关键词] 肉鸡;无机磷;植酸酶;生长性能;骨骼

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Effects of phytase and inorganic phosphorus supplementation on growth performance and bone in broiler chicks diets

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Abstract: 【Objective】 An experiment was conducted to study the effect of phytase supplementation in broilers fed on different dietary levels of inorganic phosphorus on growth performance and bone in order to determine reasonable inorganic P and phytase level. 【Method】 A total of 1500 broilers were chosen and grouped randomly into five experimental treatments. A control group with 16.3 g/kg dicalcium phosphate in diet was used, and the other four dicalcium phosphate groups were performed by 12.3, 8.2, 4.1 and 0 addition with phytase supplementation by 500 FTU/kg respectively. Dietary Ca: Tp ratio between 1.2 to 1.4

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was controlled in all treatments. The tibia fresh weight, fat-free weight, tibia ash, mineral elements contents and tibia breaking strength were monitored.【Result】 The results demonstrated that feed intake and ADG of no dicalcium phosphorus addition group was significantly lower than that of the control $P<0.05$). ADG of 8.2 g/kg calcium phosphate dibasic group was the highest and feed gain ratio was the lowest among groups. Tibia fresh weight and tibia fat-free rate were not significantly different of all treatments ($P>0.05$), and tibia fat-free rate was increased in response to decreasing inorganic P levels; Tibia fat-free weight was decreased in response to decreasing inorganic P, and it was significantly lower than that of the other groups on 28 d of the age ($P<0.05$). Tibia ash content of no dicalcium phosphorus addition group was lower than that of the other groups on 28 d of the age ($P<0.05$). Tibia Ca, tibia P contents of no dicalcium phosphorus addition group were lower than that of the other groups, but they did not show significant difference ($P>0.05$) among all treatments. Tibia Mg, tibia Mn, tibia Cu, tibia Fe, tibia Zn contents increased in response to decreasing dietary inorganic P on 28 d of age, Tibia Mg, tibia Mn, tibia Fe contents with phytase addition groups had the same variation on 42 d of age. Tibia breaking strength of no dicalcium phosphorus addition group was lower than that of the other groups, and it was lower significantly than that of the other groups on 28 d of the age ($P<0.05$).【Conclusion】 The study indicated that the growth performance and utilization of the mineral elements were improved with phytase addition in diet, but it can not replace calcium phosphate dibasic completely and 8.2 g/kg dicalcium phosphorus group (0－4 W, Ca 7.6 g/kg, TP 5.4 g/kg; 5－7 W, Ca 7.0 g/kg, TP 5.3 g/kg) with phytase addition appears to provide better efficacy in broiler breeding. In view of contribution of phytase on releasing binding minerals, it is necessary to reevaluate dietary requirements of mineral elements.

Key words: broiler; phosphorus; phytase; growth performance; bone

家禽日粮的主要成分来自植物性原料，植物籽实中 60%～80%的磷以植酸形式存在，但家禽对植酸磷的利用率很低，而且植酸还与其他一些矿物元素、蛋白质、氨基酸等络合，影响机体的吸收[1-4]。植酸酶作为饲料添加剂能够降低无机磷源添加量，提高养分利用率，减少环境污染[5-8]。研究显示，在钙磷比例适宜的情况下，植酸酶能得到更好地利用，当钙磷比在 1.1～1.4 时，动物表现出较好的生产性能[9-12]。但有关在适宜钙磷比条件下，添加植酸酶并减少磷酸氢钙用量，特别是日粮配方中不添加无机磷的研究很少见报道。另外，有关植酸酶对微量元素利用的影响研究较少，且结论不一[13-15]。

本试验在适当钙磷比例条件下，研究日粮中添加不同量无机磷后再添加植酸酶，对肉鸡生长性能及骨骼的影响，以期为生产中合理应用植酸酶及确定最佳无机磷的用量提供理论依据。

1 材料与方法

1.1 试验材料

植酸酶由广东肇庆星湖生物科技有限公司提供，活性为 5 000 FTU/g。酶活力单位定义为：在 37 ℃水浴温度和 pH 5.5 的条件下，每 min 从 5.1 mmol/L 植酸钠溶液中释放出 1 μmol 无机磷所需要的植酸酶数量[6]。

1.2 试验动物与试验设计

选取 1 500 只 1 日龄 AA 肉仔鸡，随机分为 5 个处理，每处理 3 个重复，每重复 100 只鸡，各处理肉鸡初始体重差异不显著。试验期 49 d，分为 2 个阶段：肉小鸡(0～4 周)和肉大鸡(5～7 周)阶段。对照组(CK)日粮中添加 16.3 g/kg 磷酸氢钙，不添加植酸酶，其余 4 组分别添加 12.3，8.2，4.1 和 0 g/kg 磷酸氢钙后，再均添加植酸酶 0.1 g/kg (500 FTU/kg)。

试验日粮设计参照爱拔益加商品代肉鸡营养标准，各组日粮配方组成见表 1。各处理组日粮营养水平见表 2，其中除钙磷水平不同，钙与总磷比值(钙磷比)为 1.2～1.4，其他营养水平一致。

1.3 饲养管理

饲养方式采用网上平养，乳头式饮水器，自由饮水和采食，防疫依常规进行。

1.4 指标测定及方法

试验期间每天记录采食量，于 28 和 49 日龄早晨空腹称重。从每处理各个重复中分别抽取 3 只与平均体重相近的鸡，屠宰后剥离试验鸡的左胫骨并

称重。胫骨中的脂肪、灰分含量测定按常规方法进行[16];胫骨灰分中钙、镁、铜、锰、铁、锌含量,采用英国(PYE)SP9-400 原子吸收分光光度计(Atomic Absorption Spectrophotometer)测定;磷含量采用钼黄比色法测定[16]。

胫骨折断强度采用 WDW-10 微机控制万能试验机测定,将胫骨横放在仪器支架上,跨距选为 20 mm,压头直径 15 mm,最大试验力 10 kN,速度 10 mm/min,启动仪器,在胫骨中间施加压力至断裂,记录所加压力的值[6]。

表 1　肉鸡不同生长阶段各处理组日粮的组成

Table 1　Dietary composition of all treatment groups in different chicken growing phases　　g/kg

原料 Ingredients	0～4 周 0－4 weeks					5～7 周 5－7 weeks				
	Ⅰ(CK)	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅰ(CK)	Ⅱ	Ⅲ	Ⅳ	Ⅴ
玉米 Maize meal	589.7	594.7	603.0	591.1	576.9	636.3	641.9	647.4	637.8	625.9
次粉 Wheat middling and red dog	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
豆粕 Soybean meal	218.1	218.0	215.7	212.6	209.2	181.0	180.0	180.0	177.0	174.1
棉粕 Cottonseed meal	40.0	40.0	40.0	40.0	40.0	30.0	30.0	30.0	30.0	30.0
花生粕 Peanut meal	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
玉米蛋白粉 Corn gluten meal	40.0	40.0	40.0	40.0	40.0	30.0	30.0	30.0	30.0	30.0
米糠 Rice bran	—	—	—	17.9	38.2	—	—	—	15.4	32.9
磷酸氢钙 $CaHPO_4$	16.3	12.3	8.2	4.1	0	15.5	11.6	7.8	3.9	0
石粉 Limestone	7.9	8.9	9.5	10.7	12.1	7.3	8.2	8.7	9.8	11.0
食盐 Salt	3.5	3.5	3.5	3.5	3.5	3.0	3.0	3.0	3.0	3.0
植酸酶 Phytase	—	0.1	0.1	0.1	0.1	—	0.1	0.1	0.1	0.1
豆油 Soy oil	4.5	2.5	—	—	—	16.9	15.2	13.0	13.0	13.0
预混料 Premix	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
合计 Total	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000

注:0～4 周肉仔鸡每 kg 日粮中维生素添加量为:维生素 A 15 300 IU,维生素 D_3 3 740 IU,维生素 E 40.8 IU,维生素 K_3 5.1 mg,维生素 B_1 3.4 mg,维生素 B_2 10.2 mg,维生素 B_6 5.1 mg,维生素 B_{12} 0.020 4 mg,泛酸 15.3 mg,烟酸 61.2 mg,生物素 0.204 mg,叶酸 1.7 mg;5～7 周肉仔鸡每 kg 日粮中维生素添加量为:维生素 A 13 500 IU,维生素 D_3 3 300 IU,维生素 E 36 IU,维生素 K_3 4.5 mg,维生素 B_1 3 mg,维生素 B_2 9 mg,维生素 B_6 4.5 mg,维生素 B_{12} 0.018 mg,泛酸 13.5 mg,烟酸 54 mg,生物素 0.18 mg,叶酸 1.5 mg。每 kg 日粮中微量元素添加量为:Mn 108 mg,Fe 100 mg,Zn 88 mg,Cu 9.6 mg,I 0.374 mg,Se 0.224 mg。

Note:Supplied vitamins for per kilogram of diet in 0－4 weeks chicks:V_A 15 300 IU,VD_3 3 740 IU,VE 40.8 IU,VK_3 5.1 mg,VB_1 3.4 mg,VB_2 10.2 mg,VB_6 5.1 mg,VB_{12} 0.020 4 mg,pantothenic 15.3 mg,niacin 61.2 mg,biotin 0.204 mg;folic acid 1.7 mg;supplied vitamins for per kilogram of diet in 5－7 weeks chicks:V_A 13 500 IU,VD_3 3 300 IU,VE 36 IU,VK_3 4.5 mg,VB_1 3 mg,VB_2 9 mg,VB_6 4.5 mg,VB_{12} 0.018 mg,pantothenic 13.5 mg,niacin 54 mg,biotin 0.18 mg,folic acid 1.5 mg. Supplied trace elements for per kilogram of diet: manganese 108 mg;iron 100 mg;zinc 88 mg;copper 9.6 mg;iodine 0.374 mg;selenium 0.224 mg.

表 2　肉鸡不同生长阶段各处理组日粮的营养水平

Table 2　Dietary nutrient levels of all treatment groups in different chicken growing phases

营养水平 Nutrient levels	0～4 周 0－4 weeks					5～7 周 5－7 weeks				
	Ⅰ(CK)	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅰ(CK)	Ⅱ	Ⅲ	Ⅳ	Ⅴ
代谢能/(MJ·kg^{-1}) ME	11.78	11.78	11.78	11.78	11.78	12.36	12.34	12.33	12.35	12.36
粗蛋白/(g·kg^{-1}) CP	210.6	210.6	210.6	210.6	210.6	18.5	185.0	185.0	185.0	185.0
钙/(g·kg^{-1}) Ca	9.0	8.4	7.6	7.0	6.4	8.1	7.9	7.0	6.2	5.5
总磷/(g·kg^{-1}) TP	6.8	6.1	5.4	5.0	4.6	6.6	5.9	5.3	4.7	4.2
有效磷/(g·kg^{-1}) AP	4.5	4.2	3.8	3.2	2.6	4.2	4.0	3.6	3.0	2.4
钙∶总磷 Ca∶TP ratio	1.32	1.38	1.4	1.4	1.39	1.23	1.34	1.32	1.32	1.31
赖氨酸/(g·kg^{-1}) Lys	11.0	11.1	11.1	11.1	11.1	9.8	9.9	9.9	9.9	9.9
蛋氨酸+胱氨酸/(g·kg^{-1}) Met+Cys	8.2	8.2	8.2	8.2	8.2	7.5	7.5	7.5	7.5	7.5
苏氨酸/(g·kg^{-1}) Thr	7.7	7.7	7.7	7.7	7.7	7.0	7.0	7.0	7.0	7.0

1.5　数据分析

试验数据采用 SPSS 软件进行单因素方差分析,邓肯氏(Duncan)法多重比较,数据以“平均数±标准误”表示。

2　结果与分析

2.1　不同无机磷水平日粮中添加植酸酶对肉鸡生长性能的影响

由表 3 中可以看出,0～7 周,Ⅳ、Ⅴ两组肉鸡的

日平均采食量显著低于Ⅰ、Ⅱ、Ⅲ组($P<0.05$),说明Ⅳ、Ⅴ组日粮中极低的无机磷水平使肉鸡的采食量受到了一定影响。Ⅴ组日增重显著低于Ⅰ、Ⅱ、Ⅲ组($P<0.05$),其中Ⅲ组日增重最高。Ⅴ组肉鸡料重比显著高于其他各组($P<0.05$),其中Ⅲ组的料重比最低。

表 3 不同无机磷水平日粮中添加植酸酶对肉鸡生长性能的影响

Table 3 Effect of phytase addition on growth performance in broilers fed different dietary levels of inorganic phosphorus

周龄/周 Week age	指标 Inder	处理 Treatments				
		Ⅰ(CK)	Ⅱ	Ⅲ	Ⅳ	Ⅴ
0～4	日平均采食量/(g·d^{-1}) ADFI	73.6±0.45 a	73.7±0.53 a	74.0±0.51 a	72.2±0.37 b	71.6±0.30 b
	日增重/(g·d^{-1}) ADG	47.1±0.41 a	46.2±0.72 a	46.7±0.52 a	46.8±0.74 a	43.8±0.66 b
	料重比 F/G	1.56±0.03 a	1.60±0.02 ab	1.59±0.01 ab	1.54±0.02 a	1.64±0.03 b
5～7	日平均采食量/(g·d^{-1}) ADFI	170.0±1.07 a	171.3±0.92 a	169.8±0.94 a	162.4±0.37 b	164.4±0.52 b
	日增重/(g·d^{-1}) ADG	83.1±1.01 ab	86.1±0.39 a	86.3±3.42 a	76.7±2.54 bc	74.0±2.93 c
	料重比 F/G	2.05±0.01 ab	1.99±0.02 a	1.97±0.08 a	2.12±0.07 ab	2.23±0.08 b
5～7	日平均采食量/(g·d^{-1}) ADFI	114.9±0.59 a	116.1±0.60 a	115.1±0.35 a	110.9±0.17 b	111.4±0.19 b
	日增重/(g·d^{-1}) ADG	62.6±0.49 ab	63.3±0.43 a	63.7±1.28 a	59.6±1.09 bc	56.7±1.35 c
	料重比 F/G	1.84±0.01 a	1.83±0.01 a	1.81±0.04 a	1.86±0.03 a	1.97±0.04 b

注:同列数据后标不同字母者表示差异显著($P<0.05$)。下表同。

Note: Values within a column followed by different letters were significantly different($P<0.05$). The same below.

2.2 不同无机磷水平日粮中添加植酸酶对肉鸡胫骨鲜重、脱脂重及脱脂率的影响

由表 4 可以看出,肉鸡胫骨鲜重和脱脂率在各处理间差异均不显著($P>0.05$),胫骨脱脂率随日粮中无机磷水平降低有升高的趋势;胫骨脱脂重随无机磷水平降低有下降的趋势,其中 28 日龄肉鸡未添加无机磷组(Ⅴ组)与其他各组差异显著($P<0.05$)。

表 4 不同无机磷水平日粮中添加植酸酶对肉鸡胫骨鲜重、脱脂重及脱脂率的影响

Table 4 Effect of phytase supplementation on tibia fresh weight, tibia fat-free weight and tibia fatfree rate on broiler chicks fed different dietary inorganic phosphorus levels

处理 Treatments	28 日龄 At 28 d of age			42 日龄 At 42 d of age		
	胫骨鲜重/g Tibia fresh weight	胫骨脱脂重/g Tibia fat-free weight	胫骨脱脂率/% Tibia fat-free rate	胫骨鲜重/g Tibia fresh weight	胫骨脱脂重/g Tibia fat-free weight	胫骨脱脂率/% Tibia fat-free rate
Ⅰ(CK)	7.60±0.16	2.93±0.07 a	13.62±1.55	13.71±0.38	5.57±0.25	21.66±0.53
Ⅱ	7.47±0.18	2.86±0.09 a	14.27±1.97	12.56±0.87	5.00±0.28	21.31±0.48
Ⅲ	7.36±0.39	2.82±0.12 a	14.37±2.35	13.57±0.84	5.28±0.28	21.82±1.47
Ⅳ	7.73±0.24	2.74±0.17 a	16.40±2.30	13.21±0.12	4.96±0.14	21.95±0.84
Ⅴ	7.76±0.20	2.11±0.15 b	16.91±1.62	13.90±0.62	4.95±0.20	22.13±1.34

2.3 不同无机磷水平日粮中添加植酸酶对肉鸡胫骨灰分及矿物质元素含量的影响

由表 5 可以看出,肉鸡胫骨灰分、磷、钙含量均以未添加无机磷组低于其他各组,其中 28 日龄肉鸡胫骨灰分含量以未添加无机磷组显著低于($P<0.05$)其他各组;28 日龄肉鸡胫骨镁、锰、铜、铁、锌含量随日粮中无机磷水平降低呈逐渐升高趋势;42 日龄添加植酸酶的各组肉鸡胫骨镁、锰、铁含量随日粮中无机磷水平降低呈逐渐升高趋势,Ⅰ、Ⅴ组肉鸡胫骨铜含量显著低于其他 3 组($P<0.05$),胫骨锌含量在各组肉鸡间差异不显著。

2.4 不同无机磷水平日粮中添加植酸酶对肉鸡胫骨折断强度的影响

表 6 显示,28 和 42 日龄肉鸡胫骨折断强度均以未添加无机磷组最低,其中 28 日龄该组肉鸡与其他各组差异显著($P<0.05$),以Ⅱ组折断强度最大,Ⅲ、Ⅳ组与对照组较为接近。

表 5　不同无机磷水平日粮中添加植酸酶对肉鸡胫骨灰分及矿物质元素含量的影响

Table 5　Effect of tibia ash and mineral element contents on broiler with phytase addition feeding different dietary inorganic phosphorus levels

周龄/周 Week age	指标 Inder	处理 Treatments				
		Ⅰ(CK)	Ⅱ	Ⅲ	Ⅳ	Ⅴ
28 日龄 At 28 of age	灰分/(g·kg^{-1}) Ash	441.1±1.00 a	442.9±0.54 a	445.1±1.10 a	427.3±1.50 a	390.6±0.75 b
	磷/(g·kg^{-1}) P	68.4±0.11	69.7±0.24	68.5±0.27	68.1±0.04	67.8±0.36
	钙/(g·kg^{-1}) Ca	142.7±0.58	145.1±0.80	158.6±1.13	157.7±0.83	142.3±1.13
	镁/(g·kg^{-1}) Mg	3.4±0.01	3.4±0.01	3.5±0.03	3.7±0.03	3.9±0.05
	铜/(mg·kg^{-1}) Cu	4.35±0.15 a	4.55±0.44 a	5.27±0.41 ab	5.29±0.44 ab	6.08±0.43 b
	锌/(mg·kg^{-1}) Zn	168.08±4.28 a	168.92±3.37 a	178.33±9.75 a	187.97±7.76 a	216.54±5.88 b
	铁/(mg·kg^{-1}) Fe	190.99±13.34 a	293.75± 30.2 b	307.56±25.18 b	338.55±68.61 b	524.01±15.23 c
	锰/(mg·kg^{-1}) Mn	6.86±0.28	6.99±0.26	7.91±0.76	8.31±0.98	8.52±0.76
42 日龄 At 42 of age	灰分/(g·kg^{-1}) Ash	378.2±0.46	395.2±0.95	386.0±0.85	383.2±0.90	369.8±0.62
	磷/(g·kg^{-1}) P	65.9±0.12	67.5±0.17	66.0±0.15	65.0±0.12	64.1±0.13
	钙/(g·kg^{-1}) Ca	120.9±0.23	128.1±0.36	122.2±0.49	121.3±0.36	120.7±0.26
	镁/(g·kg^{-1}) Mg	3.06±0.01 a	3.07±0.01 a	3.12±0.01 a	3.20±0.01 a	3.64±0.03 b
	铜/(mg·kg^{-1}) Cu	4.31±0.24 a	7.10±0.63 b	7.12±0.21 b	6.25±0.71 b	4.33±0.25 a
	锌/(mg·kg^{-1})Zn	130.75±4.61	130.86±2.52	131.29±5.07	124.45±4.97	129.84±3.39
	铁/(mg·kg^{-1}) Fe	299.83±50.44	256.84±12.20	274.96±21.61	289.21±27.69	301.16±17.84
	锰/(mg·kg^{-1}) Mn	6.36±0.06	6.44±0.20	6.63±0.64	6.82±0.29	6.95±0.19

注:表中灰分和矿物质含量计算均以干物质为基础。

Note: The contents of ash and mineral elements calculated were all based on dry matter in the table.

表 6　不同无机磷水平日粮中添加植酸酶对胫骨折断强度的影响

Table 6　Effect of tibia breaking strength with phytase addition feeding different dietary inorganic phosphorus levels　N

处理 Treatments	28 日龄 At 28 d of age	42 日龄 At 42 d of age
Ⅰ(CK)	238.24±7.56 a	330.79±31.29
Ⅱ	253.59±7.34 a	356.41±45.61
Ⅲ	239.73±11.52 a	336.44±23.77
Ⅳ	224.90±6.82 a	327.67±33.55
Ⅴ	168.95±12.14 b	296.03±17.37

3　讨　论

3.1　不同无机磷水平日粮中添加植酸酶对肉鸡生长性能的影响

本研究表明,12.3 和 8.2 g/kg 磷酸氢钙组添加植酸酶后,肉鸡日平均采食量增加,生长性能提高。韩进诚等[17]报道,日粮中添加植酸酶提高了青年蛋鸡的采食量。Sebastian 等[4]研究表明,在肉鸡低磷-低钙日粮中添加植酸酶能获得较好的生长性能,这与本研究结果一致。本研究中,无无机磷组添加植酸酶使肉鸡生长性能下降,与张铁鹰等[18]的研究结果一致,表明肉鸡玉米-豆粕型日粮中添加植酸酶,不能全部替代日粮中的磷酸氢钙。相反,Broz 等[19]研究表明,未添加无机磷的低磷日粮显著提高了肉鸡的生长性能,究其原因是由于其配方中添加了鱼粉,实际是提供了一部分非植酸磷的营养,从而能获得较好的生产性能,而目前肉鸡配方中大都不添加鱼粉。由本研究结果可以看出,非植酸磷添加水平和植酸酶添加量与肉鸡生长性能相关,这与 Peter 等[20]的报道一致。本研究结果显示,8.2 g/kg磷酸氢钙组添加植酸酶对提高肉鸡生产性能的效果最佳,而不是 12.3 g/kg 磷酸氢钙组,可能有以下原因:一是无机磷,也就是植酸酶水解的终产物,抑制了植酸酶的催化活性[21];二是植酸酶提高了磷的释放,可能在胃肠道中导致钙磷之间的不平衡;三是可能破坏了日粮的电解质平衡(DEB),这是因为植酸和植酸盐会影响钠在肠腔的分泌[22-23]。

3.2　不同无机磷水平日粮中添加植酸酶对肉鸡胫骨鲜重、脱脂重及脱脂率的影响

日粮中添加植酸酶对于胫骨鲜重及脱脂率的影响报道较少。Veum 等[24]研究表明,随日粮中植酸酶浓度的增加,仔猪趾骨鲜重及脱脂重呈线性提高。本研究结果显示,日粮中添加植酸酶以未添加无机磷组肉鸡的胫骨鲜重最高,这是否说明由于矿物质含量不足出现了代偿生长,尚有待进一步证实;胫骨脱脂重随无机磷水平降低而下降,胫骨脱脂率随无机磷水平降低呈升高趋势,说明添加植酸酶对胫骨中的脂肪含量产生了一定影响,胫骨脱脂率高表明骨中有机质含量高而无机质含量相对较少,从而导致骨弹性强而硬度不够,无无机磷组的胫骨脱脂率最高,说明骨的硬度相对较差。

3.3 不同无机磷水平日粮中添加植酸酶对肉鸡胫骨灰分及矿物质元素含量的影响

骨灰分含量被广泛用来作为评估磷需要量的标准,因为对于磷缺乏日粮,该指标比生长率更为敏感[6,8,25]。由本研究结果可以看出,12.3 和 8.2 g/kg 磷酸氢钙组肉鸡胫骨灰分及胫骨中钙、磷含量均高于对照组,说明添加植酸酶提高了胫骨中灰分及钙、磷含量,这与 Broz 等[19]、Viveros 等[26]和 Onyango 等[27]的研究结果一致,Lan 等[28]研究结果显示,添加植被酶仅提高了胫骨灰分及钙含量,但磷含量未受到影响。

本研究结果中,28 日龄肉鸡胫骨中镁、铜、锰、铁、锌含量均随日粮无机磷水平降低呈逐渐升高趋势,42 日龄肉鸡胫骨中镁、锰、铁含量在各添加植酸酶组也有同样的变化趋势,说明添加植酸酶提高了矿质元素的利用率,并且在日粮含磷水平越低时,植酸酶应答越大,植酸酶的释放能力越强[29-30]。Robert 等[13]研究表明,日粮中添加植酸酶提高了肉鸡胫骨锌、锰的含量;Shelton 等[14]报道,日粮中添加植酸酶后,提高了猪对锌、铁、锰的吸收但降低了对铜的吸收;Adeola 等[15]研究显示,日粮中添加植酸酶未影响猪对镁、锰的吸收,但能提高对锌、铜的吸收;Zanini 等[31]研究表明,日粮中添加植酸酶提高了肉鸡骨骼中锌的浓度;Stahl 等[32]研究表明,日粮中添加植酸酶能提高猪对铁的生物学利用率;Viveros 等[26]研究显示,日粮中添加植酸酶能提高肉鸡胫骨中镁、锌的含量。本研究结果基本证实了上述观点。

3.4 不同无机磷水平日粮中添加植酸酶对肉鸡胫骨折断强度的影响

本研究结果表明,12.3 和 8.2 g/kg 磷酸氢钙组添加植酸酶后,肉鸡胫骨折断强度均大于对照组,这与 Sohail 等[33]和 Onyango 等[27]的研究结果一致,说明日粮中添加植酸酶提高了骨骼强度。Sohail 等[33]的研究还表明,在低磷日粮中添加植酸酶对肉鸡骨骼强度的影响更大。本试验结果中,8.2 和 4.1 g/kg 磷酸氢钙组添加植酸酶后,与对照组胫骨折断强度较为接近,证实了上述结论。而无无机磷组添加植酸酶后,肉鸡胫骨折断强度远低于对照组,说明用植酸酶完全替代磷酸氢钙效果并不理想。

4 结 论

在低无机磷水平日粮中添加植酸酶,能提高肉鸡生长性能,促进骨骼矿物质沉积,提高矿物质元素利用率,并随日粮中无机磷水平降低,植酸酶发挥的作用增加,但日粮中完全不添加无机磷并不可取。在钙磷比为 1.2～1.4 时,以 8.2 g/kg 磷酸氢钙组(0～4 周龄:Ca 7.6 g/kg,总磷(TP)5.4 g/kg;5～7 周龄:Ca 7.0 g/kg,TP 5.3 g/kg)添加植酸酶效果较好。值得关注的是,由于植酸酶对矿物质元素具有释放作用,有必要重新评定日粮配方中矿物质元素的需要量。

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地衣芽孢杆菌对 0～3 周龄肉仔鸡的影响

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[摘 要] 【目的】研究耐制粒(制粒条件 0.1 MPa，65 ℃)地衣芽孢杆菌对 0～3 周龄肉仔鸡生产性能、血液生化指标和粪便大肠杆菌数的影响。【方法】将自制地衣芽孢杆菌粉剂，按 3 g/kg 添加量与 1～21 日龄肉仔鸡无抗生素日粮混合，于 0.1 MPa、65 ℃条件下制成试验颗粒料饲喂 AA 肉仔鸡，试验为期 3 周，探讨耐制粒地衣芽孢杆菌对肉仔鸡生产性能、血液生化指标和粪便大肠杆菌数的影响。【结果】与对照组相比，地衣芽孢杆菌可极显著降低 1 周龄肉仔鸡的平均采食量($P<0.01$)，显著提高 3 周龄肉仔鸡的血糖(GLU)水平($P<0.05$)，显著降低肠道大肠杆菌数($P<0.01$)。地衣芽孢菌对肉仔鸡其他生产和血液生化指标无显著影响。【结论】地衣芽孢杆菌对提高雏鸡的生产性能、降低肠道大肠杆菌具有一定的促进作用，可提高 3 周龄肉仔鸡血糖含量，而对所测其他生产和血清生化指标无显著影响。

[关键词] 地衣芽孢杆菌；生产性能；血液生化指标；大肠杆菌

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Effect of *Bacillus licheniformis* on broiler aged 0－3 weeks

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Abstract: 【Objective】 An experiment was conducted using a total of 96 day-old Arbor Acres broilers to investigate the effects of *Bacillus licheniformis* on performance, blood biochemical indexes and *E. coli* of feces during 0－3 weeks of age. 【Method】 Bacillus licheniformis were mixed with 1－21 days feed at supplement amount 3 g/kg and were pelleted under the condition of 0.1 MPa, 65 ℃, which were used to study the effects of *Bacillus licheniformis* on performance, blood biochemical indexes and *E. coli* of feces during 0－3 weeks of age. 【Result】 The result showed that: Bacillus licheniformis could decrease ADFI of 1 week broilers ($P>0.05$); Bacillus licheniformis could improve GLU level of 3 weeks broilers ($P<0.05$); And bacillus licheniformis could significantly decrease *E. coli* of feces ($P<0.01$). 【Conclusion】 *Bacillus licheniformis* could improve performance and decrease *E. coli* of feces.

Key words: *Bacillus licheniformis*; performance; biochemical index; *E. coli*

雏鸡肠道微生态系统尚处于开始建立、逐步成熟的阶段，上皮细胞没有被正常菌群所占据，黏膜免疫及系统免疫功能不健全，对进入肠道的抗原抵御能力不足。益生菌对促进肠道微生态系统发育、提高免疫

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