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Effect of phytase supplementation on performance, bone densitometry and carcass yield in broilers chicks

Otto Mack Junqueira[1], Karina Ferreira Duarte[1*], Vinícius Assuena[1], Rosemeire da Silva Filardi[2], Antonio Carlos de Laurentiz[2] and Maria Fernanda Ferreira Menegucci Praes[1]

*[1]Departamento de Zootecnia, Faculdade de Ciências Agrárias e Veterinárias de Jaboticabal, Universidade Estadual Paulista "Júlio de Mesquita Filho", Via de Acesso Prof. Paulo Donato Castellane, 14884-900, Jaboticabal, São Paulo, Brazil. [2]Departamento de Biologia, Faculdade de Engenharia de Ilha Solteira, Universidade Estadual Paulista "Júlio de Mesquita Filho", Ilha Solteira, São Paulo, Brazil. *Author for correspondence. E-mail: karinafduarte@yahoo.com.br*

ABSTRACT. An experiment was conducted to evaluate the performance, bone densitometry and carcass yield of broilers chicks, using different levels of phytase enzyme. Nine hundred and sixty male one-day-old broiler chicks were used. The birds were distributed in a completely randomized experimental design, involving five treatments and six replications of 32 chicks each. The treatments consisted of a control diet for each phase, and four other diets were formulated adding growing levels of the phytase enzyme (250, 500, 750 and 1,000 FTU of phytase kg^{-1} feed). When adding the phytase enzyme, the nutritional matrix was valued to guarantee the same nutritional levels as the control diet. In general, the addition of phytase enzyme determined a linear decrease on the performance of the birds. However, the performance obtained with the level of 250 FTU phytase kg^{-1} feed were no different from the control treatment. The best bone density results were observed in the control treatment with no phytase, and the highest leg and thigh yield were obtained at the level of 514 FTU phytase kg^{-1}.

Keywords: bone characteristics, carcass yield, performance, phytase enzyme.

RESUMO. Efeito da adição da enzima fitase sobre o desempenho, densitometria óssea e rendimento de carcaça de frangos de corte. Um experimento foi realizado com o objetivo de avaliar a inclusão de diferentes níveis da enzima fitase, sobre o desempenho, a densitometria óssea e o rendimento de carcaça e partes de frangos de corte nas diferentes fases de criação. Foram utilizados 960 pintainhos de corte com um dia de idade, da marca comercial Ross, distribuídos em um delineamento inteiramente casualizado, com quatro tratamentos mais uma testemunha (quatro níveis da enzima fitase - 250, 500, 750 e 1.000 FTU de fitase kg^{-1} de ração + testemunha) e seis repetições de 32 aves cada. Ao adicionar a enzima fitase, a matriz nutricional da mesma foi valorizada para garantir os mesmos níveis nutricionais da dieta testemunha. Foram avaliados os índices de desempenho, de densitometria óssea e o rendimento de carcaça e de partes nas diferentes fases de criação. De maneira geral o aumento na inclusão da enzima fitase determinou declínio linear sobre o desempenho das aves. Entretanto, até o nível de 250 FTU de fitase kg^{-1} de ração não foram observadas diferenças expressivas em relação ao tratamento isento de fitase. Os melhores resultados de densitometria óssea foram observados no tratamento controle sem a adição da enzima fitase e o maior rendimento de coxa+sobrecoxa foi obtido com o nível de 514 FTU de fitase kg^{-1} de ração.

Palavras-chave: características ósseas, desempenho, enzima fitase, rendimento de carcaça.

Introduction

Phytase is an enzyme which dephosphorylates the phytate molecule, resulting in the release of phosphorus (P) and other cations to be used by the broiler. Increased phytate availability decreases the need for inorganic P to meet the broiler's P requirement, and the increase in available P decreases P excretion by improving the use of phytate-bound P (PAYNE et al., 2005).

The phytate form of P in plant feedstuff represents 60 to 70% of the total P (TP). Phytate P (PP) is utilized from 0 to 50% in poultry, depending on age and metabolic adaptation in critical circumstances. Poultry lack significant amounts of endogenous phytase that can hydrolyze phytic acid (DENBOW et al., 1995; COOPER; GOWING, 1983). In general, broiler P requirements are met in feed formulations with either non-phytate phosphorus (NPP) or a combination of NPP and released P from PP with a commercial phytase. The dietary addition of feed phosphates not only increases feed and production cost, but may also lead to an increase of soluble P in litter, resulting in the potential for water contamination from excess P in the soil. The maximum utilization of feed PP by poultry with the addition of exogenous dietary phytase should help in reducing the amount of dietary NPP supplementation needed and decrease potential environmental pollution. Phytate can also form complexes with proteins, starch, and metal ions such as calcium, magnesium, iron, and zinc, thereby producing an antinutritional effect (COSGROVE, 1980).

Phytases are found naturally in a number of seeds including cereals, legumes, by-products and other feedstuffs (EECKHOUT; DE PAEPE, 1994; VIVEROS et al., 2000), and in microbial sources (WYSS et al., 1999). Commercial phytases are typically produced using recombinant DNA technology. Supplementation of diets with microbial phytase increases availability of phytate P and Zn in chicks (MOHANNA; NYS, 1999; QIAN et al., 1997; RAVINDRAN et al., 2000; SEBASTIAN et al., 1996). Phytase also increases availability and retention of Ca (QIAN et al., 1996, 1997; SEBASTIAN et al., 1996) and improves absorption and retention of Mg, Cu, and Fe (PALLAUF et al., 1992; SEBASTIAN et al., 1996). In contrast, Roberson and Edwards Jr. (1994) showed that microbial phytase supplementation does not influence Zn retention. Therefore, the aim of this experiment was to evaluate the influence of different levels of dietary phytase on performance and carcass yield in broiler chickens during the starter (1 to 21 days), grower (22 to 42 days), and total (1 to 42 days) rearing phases.

Material and methods

A total of 960 male Ross broilers were reared from 1 to 42 days of age in a conventional broiler house. The experimental period was divided in two phases: starter (1 to 21 days of age) and grower (22 to 42 days of age) rearing periods.

A completely randomized experimental design was applied, including five treatments with six replications of 32 birds each. Treatments consisted of a control diet and four other diets formulated adding growing levels of the phytase enzyme (250, 500, 750 and 1,000 FTU kg^{-1} of feed). Phytase nutritional matrix was considered in feed formulation; therefore, all experimental diets contained the same nutritional levels as the control diet.

The experimental diets were based on corn and soybean meal, and were formulated according to the nutritional recommendations and ingredient composition described by Rostagno et al. (2005). Diet composition and nutritional levels fed during the starter (1 to 21 days of age) and grower (22 to 42 days of age) phases are presented in Tables 1 and 2, respectively. Table 2 shows the nutritional matrix of the commercial enzyme product Natuphos® 10000[1] for broilers, as described by the manufacturer for an inclusion of 50 g enzyme ton^{-1} feed, ensuring 500 FTU kg^{-1} of feed.

Weight gain, feed intake and feed conversion ratio were determined for each rearing phase. At the end of the experimental period (42 days of age), the production efficiency index (PEI = [daily weight gain (g) x L (%)]/(feed conversion ratio x 10)) and livability (L (%)= [total number of birds - (number of dead + culled birds)/total number of birds]) were calculated.

At the end of each experimental phase, ten birds per treatment were sacrificed for collection of the tibiotarsal bone. After removing soft tissues and ligaments, the bones were radiographed to determine bone densitometry. A penetrometer or 12-degree aluminum scale (alloy 6063, ABNT) was used as densitometry reference in the radiographs.

Densitometry readings were carried out after radiographic images were digitalized in an appropriate scanner. Data were stored using the “Image-Pro Plus Media Cybernetics” software program, version 4.1. Readings are expressed in aluminum millimeters (mm Al), according to Louzada et al. (1998).

For processing yield evaluation, 10 birds per pen were randomly selected and wing-banded. After six hours, they were weighed individually at the processing plant, slaughtered, and eviscerated. The yield was obtained for the entire carcass (without feet, head and neck), breast yield, leg and thigh yield, back yield and wing yield.

The obtained results were submitted to analysis of variance using the General Linear Model (GLM) procedure of SAS software package (SAS, 2002). Whenever significant effects ($p < 0.05$) were determined by analysis of variance, linear and quadratic polynomial regression analyses were carried out, and Tukey’s test at 5% probability was performed when significant linear effects were detected.

[1]Natuphos® 10000: commercial brand of the company BASF S/A: Estr. Samuel Aizemberg, 1707 - Bloco C - 2. Andar, São Bernardo do Campo, São Paulo, CEP 09851-550.

Table 1. Percentage composition of the experimental diets at the different rearing phases.

Ingredients (%)	Phytase inclusion levels (FTU kg^{-1})									
	Starter phase*					Grower phase**				
	Control	250	500	750	1000	Control	250	500	750	1000
Corn, grain	58.6200	59.8315	61.6810	62.9145	64.2980	66.0820	67.6155	69.1700	70.3145	71.4610
Soybean meal 45%	35.0900	34.6650	34.0220	33.5930	33.0370	24.4200	23.8720	23.3210	23.0890	22.8560
Corn gluten 60%	0.0000	0.0000	0.0000	0.0000	0.0000	3.5000	3.5000	3.5000	3.5000	3.5000
Soybean oil	2.6600	2.0530	1.1410	0.5330	0.0000	2.8400	2.0800	1.3170	0.6590	0.0000
Dicalcium phosphate	2.0300	1.7790	1.3950	1.1380	0.7540	1.8000	1.4870	1.1660	0.8440	0.5220
Limestone	0.7200	0.7840	0.8720	0.9310	1.0180	0.6500	0.7300	0.8030	0.8750	0.9470
Vitamin and mineral premix[1]	0.2000	0.2000	0.2000	0.2000	0.2000	0.1000	0.1000	0.1000	0.1000	0.1000
Salt	0.4500	0.4560	0.4560	0.4560	0.4560	0.4300	0.4290	0.4290	0.4290	0.4290
L-lysine	0.0000	0.0000	0.0000	0.0000	0.0000	0.0270	0.0340	0.0410	0.0380	0.0350
DL-methionine	0.2300	0.2290	0.2280	0.2270	0.2270	0.1510	0.1500	0.1480	0.1440	0.1400
Phytase	0.0000	0.0025	0.0050	0.0075	0.0100	0.000	0.0025	0.0050	0.0075	0.0100

[1]Enrichment per kg feed: 8,000 IU vitamin A, 1,800 IU vitamin D3, 12 mg vitamin E, 2 mg vitamin K3, 1 mg vitamin B1, 4 mg vitamin B2, 1 mg vitamin B6, 10 mcg vitamin B12, 0.40 mg folic acid, 0.04 mg biotin, 28 mg niacin, 11 mg calcium pantothenate, 6 mg Cu, 0.10 mg Co, 1 mg I, 50 mg Fe, 65 mg Mn, 45 mg Zn, 0.21 mg Se, 500 mg choline chloride 50%, 1400 mg methionine, 60 mg coccidiostat, 12 mg antioxidant. *Nutritional levels: 3,050 ME (kcal kg^{-1}), 21.14% crude protein, 0.90% calcium, 0.48% available phosphorus, 0.21% sodium, 1.12% total lysine (1.00% digestible), 0.55% total methionine (0.53% digestible), 0.89% total methionine+cystine (0.83% digestible), 0.89% total threonine (0.77% digestible), 0.26% total tryptophan (0.24% digestible), 0.99% total valine (0.89% digestible), 0.86% total isoleucine (0.77% digestible). **Nutritional levels: 3,200 ME (kcal kg^{-1}), 19.00% crude protein, 0.78% calcium, 0.43% available phosphorus, 0.20% sodium, 0.90% total lysine (0.80% digestible), 0.47% total methionine (0.45% digestible), 0.79% total methionine+cystine (0.74% digestible), 0.82% total threonine (0.71% digestible), 0.21% total tryptophan (0.19% digestible), 0.94% total valine (0.85% digestible), 0.82% total isoleucine (0.74% digestible).

Table 2. Nutritional matrix of phytase Natuphos®10000.

Nutrients	Amount
Metabolizable energy (kcal kg^{-1})	1,060,000
Crude protein (%)	4,500
Calcium (%)	2,000
Total phosphorus (%)	2,300
Digestible amino acids (%)	
Lysine	240
Methionine	20
Cystine	60
Methionine + Cystine	80
Tryptophan	60
Threonine	260
Valine	316
Isoleucine	240
Leucine	416
Arginine	274
Phenylalanine	274
Histidine	118

Results and discussion

The effects of different levels of phytase supplementation on growth performance from 1 to 21 days of age are summarized in Table 3. A negative linear effect was observed of phytase levels ($p < 0.01$) on weight gain ($\hat{y}$ = 720.0847-0.0592x; R^2 = 98.29) and feed conversion ($\hat{y}$ = 1.4161+0.0001x; R^2 = 99.32), indicating that by increasing dietary phytase levels, performance declined, and that optimal phytase levels were not achieved for these parameters in the present experiment. The addition of 1,000 FTU of phytase kg^{-1} of feed resulted in the worst feed conversion. Only feed intake was not affected by different levels of phytase ($p > 0.05$).

The results of the present experiment are not consistent with those obtained by Murata et al. (2006), who added 750 and 1,000 FTU phytase kg^{-1} of feed and considered phytase matrix nutritional values, and did not observe any significant effects on broiler performance during the starter phase. However, it must be noted that those authors did not present the composition of the nutritional matrix used in their trial. Conte et al. (2003) worked with the inclusion of 15% rice bran and four phytase levels for starter broilers, and observed that feed intake and live weight increased with enzyme inclusion, whereas feed conversion ratio was not influenced by the studied factors.

Table 3. Effect of different dietary phytase levels on weight gain, feed intake and feed conversion of broiler chicks from 1 to 21 days of age.

Treatments	Weight Gain (g)[2]	Feed Intake (g)	Feed Conversion (g g^{-1})[3]
Control	718 A	1,017	1.42 C
250 FTU kg^{-1}	710 A	1,026	1.44 BC
500 FTU kg^{-1}	688 AB	1,005	1.46 BC
750 FTU kg^{-1}	676 B	1,007	1.49 AB
1,000 FTU kg^{-1}	661 B	1,005	1.52 A
F value[1]	8.46**	0.60 ns	11.79**
CV (%)	2.88	2.83	1.96

Means followed by different letters in the same column are significantly different ($p < 0.05$) by Tukey's test. [1]ns – not significant; **significant ($p < 0.01$). [2]Linear effect of phytase levels: y = 720.0847-0.0592x; (R^2 = 98.29). [3]Linear effect of phytase levels: $\hat{y}$ = 1.4161+0.0001x; (R^2 = 99.32).

Using low available phosphorus and phytase levels, Persia and Saylor (2006) showed that phytase improved the performance from 8- to 22-day-old broilers, as opposed to Angel et al. (2006), who did not find any differences in broiler performance during the starter phase when adding phytase to low available phosphorus diets.

The effects of different levels of phytase supplementation on growth performance from 22 to 42 days of age are summarized in Table 4. The results obtained were similar to those of the starter phase, again with no effect of phytase dietary inclusion levels on feed intake ($p > 0.05$). There were linear effects ($p < 0.01$) of phytase on weight gain ($\hat{y}$ = 1621.2943-0.0869x; R^2 = 85.82) and feed conversion ratio ($\hat{y}$ = 2.0330+ 0.000058x; R^2 = 94.54), with worse results in the evaluated parameters as phytase inclusion levels increased, and an optimal phytase level was again not achieved for these parameters. The phytase dietary inclusion of 1,000 FTU kg^{-1} had a negative effect ($p < 0.01$) on feed conversion ratio, as compared to the control treatment. Also weight gain showed negative results when 750 and 1,000 FTU phytase kg^{-1} of feed where used in the diet ($p < 0.01$).

When studying dietary phytase inclusion and different phosphorus levels from 22 to 42 day of age, Wu et al. (2004) and Viveros et al. (2002) observed positive weight gain results. However, these data cannot be compared with the results of the present study because the aforementioned trials did not consider the enzyme nutritional matrix when formulating the experimental diets.

Table 4. Effect of different dietary phytase levels on weight gain, feed intake and feed conversion of broiler chicks from 22 to 42 days of age.

Treatments	Weight Gain (g)^2	Feed Intake (g)	Feed Conversion (g g^{-1})^3
Control	1,637 A	3,323	2.03 B
250 FTU kg^{-1}	1,578 AB	3,227	2.04 AB
500 FTU kg^{-1}	1,573 AB	3,252	2.07 AB
750 FTU kg^{-1}	1,562 B	3,255	2.08 AB
1,000 FTU kg^{-1}	1,536 B	3,203	2.08 A
F value^1	4.84**	2.30 ns	3.44**
CV (%)	2.62	2.24	1.52

Means followed by different letters in the same column are significantly different ($p < 0.05$) by Tukey's test. [1]ns – not significant; **significant ($p < 0.01$). [2]Linear effect of phytase levels: $\hat{y} = 1621.2943-0.0869x$; ($R^2 = 85.82$). [3]Linear effect of phytase levels: $\hat{y} = 2.0330+0.000058x$; ($R^2 = 94.54$).

The effects of different levels of phytase supplementation on growth performance from 1 to 42 days of age are summarized in Table 5. Weight gain, feed intake, and feed conversion ratio were significantly influenced ($p < 0.01$) by dietary phytase level. There were negative linear effects on weight gain ($\hat{y} = 2341.3803-0.1461x$, $R^2 = 96.03$), feed conversion ratio ($\hat{y} = 1.8433+0.00007x$; $R^2 = 98.69$) and production efficiency index ($\hat{y} = 292.077-0.0266x$; $R^2 = 85.76$). These results indicate that when phytase was added to the feeds, weight gain and production efficiency index declined, and feed conversion ratio worsened. An optimal phytase level was not achieved for these parameters. The different phytase feed inclusion levels tested significantly influenced ($p < 0.01$) weight gain, feed conversion and production efficiency index, and there was no effect ($p > 0.05$) on feed intake or viability.

When levels higher than 500 FTU phytase kg^{-1} of feed were added to the feeds, weight gain and production efficiency index were lower as compared to the control treatment. As for feed conversion ratio, the worst results were obtained when 750 and 1.000 FTU phytase kg^{-1} of feed were included. The results obtained for the total period showing that increasing phytase levels had negative effects on performance parameters are different from literature results (LAN et al., 2002; TEJEDOR et al., 2001; WU et al., 2004). However, in those papers the authors considered only the availability of phosphorus when adding the phytase enzyme, and did not consider other nutrients that are supposedly complexed in phytic acid.

The effects of different levels of phytase supplementation on bone density at 21 and 42 days of age are summarized in Table 6. There was a linear effect ($p < 0.05$) of phytase dietary level on all evaluated bone segments, indicating that bone density decreased as phytase level increased. The inclusion of 250 and 500 FTU phytase kg^{-1} of feed and no phytase supplementation (control treatment) promoted the best results. Onyango et al. (2004) evaluated the inclusion of phytase in feeds based on corn and soybean meal with reduced phosphorus content in starter broilers, and observed that bone density, bone mineral content, bone strength, and ash percentage were positively influenced by dietary phytase supplementation.

At 42 days of age, the main effect data indicate a quadratic effect ($p < 0.01$) of phytase dietary inclusion on the bone density of the studied segments of the tibiotarsal bone. Proximal epiphysis bone density decreased ($\hat{y} = 2.2897-0.00157x+0.000001x^2$; $R^2 = 67.92$) up to the level of 785 FTU, with a minimum density of 1.673 mm Al, whereas above 785 FTU, this value increased.

Table 5. Effect of different dietary phytase levels on weight gain, feed intake, feed conversion, viability and production efficiency index of broiler chicks from 1 to 42 days of age.

Treatments	Weight Gain (g)^2	Feed Intake (g)	Feed Conversion (g g^{-1})^3	Viability (%)	Production Efficiency Index^4
Control	2,355 A	4,340	1.84 B	97.43	296 A
250 FTU kg^{-1}	2,289 AB	4,253	1.86 AB	96.85	284 AB
500 FTU kg^{-1}	2,261 BC	4,258	1.88 AB	95,32	272 B
750 FTU kg^{-1}	2,239 BC	4,262	1.90 A	97.43	272 B
1,000 FTU kg^{-1}	2,191 C	4,208	1.89 A	98.44	268 B
F value^1	8.64**	1.99 ns	5.07**	1.21 ns	5.73**
CV (%)	2.17	1.94	1.49	2.63	4.17

Means followed by different letters in the same column are significantly different ($p < 0.05$) by Tukey's test. [1]ns – not significant; **significant ($p < 0.01$). [2]Linear effect of phytase levels: $\hat{y} = 2341.3803-0.1461x$ ($R^2 = 96.03$). [3]Linear effect of phytase levels: $\hat{y} = 1.8433+0.00007x$; ($R^2 = 98.69$). [4]Linear effect of phytase levels: $\hat{y} = 292.077-0.0266x$ ($R^2 = 85.76$).

Table 6. Effect of different dietary phytase levels on proximal epiphysis, diaphysis and distal epiphysis of broiler chicks from 1 to 21 and 22 to 42 days of age.

Treatments	Bone density at 21 days of age		
	Proximal epiphysis (mm Al)[2]	Diaphysis (mm Al)[3]	Distal epiphysis (mm Al)[4]
Control	1.89 AB	2.37 A	1.53 A
250 FTU kg^{-1}	1.73 AB	1.94 AB	1.26 B
500 FTU kg^{-1}	1.81 A	2.11 AB	1.41 A
750 FTU kg^{-1}	1.60 B	1.82 B	1.17 B
1,000 FTU kg^{-1}	1.67 AB	1.83 B	1.19 B
F value[1]	3.53*	3.42*	2.58*
CV (%)	17.31	19.50	26.01
	Bone density at 42 days of age		
	Proximal epiphysis (mm Al)[5]	Diaphysis (mm Al)[6]	Distal epiphysis (mm Al)[7]
Control	2.36	2.23	1.92
250 FTU kg^{-1}	1.84	1.67	1.18
500 FTU kg^{-1}	1.74	1.74	1.20
750 FTU kg^{-1}	2,02	2.19	1.51
1,000 FTU kg^{-1}	1.87	2.27	1.42
F value[1]	5.57**	8.09**	9.81**
CV (%)	16.34	15.97	20.82

Means followed by different letters in the same column are significantly different ($p < 0.05$) by Tukey's test. [1]ns - not significant ; *significant ($p < 0.05$); ** significant ($p < 0.01$). [2]Linear effect of phytase levels: $\hat{y} = 1.9127- 0.00024x$ ($R^2 = 25.40$). [3]Linear effect of phytase levels: $\hat{y} = 2.2557- 0.00048x$ ($R^2 = 68.25$). [4]Linear effect of phytase levels: $\hat{y} = 1.4860- 0.0003x$ ($R^2 =48.85$). [5]Quadratic effect of phytase levels: $\hat{y} =2.2897-0.00157x+0.000001x^2$ ($R^2 = 67.92$). [6]Quadratic effect of phytase levesl: $\hat{y} = 2.1621-0.00195x+0.000002x^2$ ($R^2 = 87.25$). [7]Quadratic effect of phytase levels: $\hat{y} = 1.8051-0.0021x+0.000002x^2$ ($R^2 = 63.00$).

In the diaphysis ($\hat{y} = 2.1621-0.00195x+0.000002x^2$; $R^2 = 87.25$), the minimum value of 1.687 mm Al was obtained with the addition of 488 FTU phytase, above which this value increased. In the distal epiphysis ($\hat{y} =1.8051-0.0021x+0.000002x^2$; $R^2 = 63.00$), the inclusion of up to 525 FTU phytase determined reducing values, with the lowest at 1.234 mm Al; above 525 FTU phytase, the obtained results increased. Considering that calcium and phosphorus are the major mineral in bone structure, the highest availability of these minerals by phytase addition can be explained by the increase in ash percentage in bone density. Broz et al. (1994), Sebastian et al. (1996), Ahmad et al. (2000) and Lan et al. (2002) also showed the increase in bone ash of the tibiotarsal bone by the addition of phytase in the broiler diets. Denbow et al. (1998) observed that the supplementation of 400, 800 and 1,200 FTU kg^{-1} phytase improved the bone density of broilers at 21 days of age. Catalá-Gregori et al. (2006) observed that birds fed diets containing different total phosphorus levels and supplemented with phytase presented lower bone ash percentage. Most studies that correlate dietary phytase inclusion with phosphorus availability and bone deposition express their results as bone ash and phosphorus percentage and as bone strength (BANKS et al., 2006; MARTINEZ-AMEZCUA et al., 2006; OLIVEIRA et al., 2008; PAYNE et al., 2005; PERSIA; SAYLOR, 2006), and suggest that the inclusion of phytase in diets with different available phosphorus levels promote higher ash content or tibia strength.

Data from carcass yield and parts are shown in Table 7. There was a quadratic effect for leg and thigh ($\hat{y} = 30.4581+0.0051x–0.000005x^2$ $R^2 = 64.97$), and the derivation indicated that the addition of phytase up to 514 FTU kg^{-1} of feed promotes an increase in yield. Other values for yield were not affected ($p > 0.05$) by phytase levels. These results are in agreement with Bharathidhasan et al. (2009), who observed a marginal increase in dressing percentage and carcass yield in birds fed with diets containing enzyme level at 0, 250, 500, 750 and 1,000 g ton^{-1} of feed. Also, Jordão Filho et al. (2006) did not find differences using 500 until 1,500 FTU phytase kg^{-1} of feed.

Table 7. Effect of different dietary phytase levels on carcass yield, breast yield, leg and thigh yield, wing yield and back yield of broiler chicks at 42 days of age.

Treatments	Carcass Yield (%)	Breast Yield (%)	Leg and Thigh Yield (%)[2]	Wing Yield (%)	Back Yield (%)
Control	69.09	32.91	32.39 A	10.75	22.49
250 FTU kg^{-1}	69.97	32.47	31.22 AB	10.75	23.61
500 FTU kg^{-1}	69.14	33.24	31.55 AB	11.19	22.77
750 FTU kg^{-1}	68.69	31.84	30.63 B	11.01	22.83
1,000 FTU kg^{-1}	69.51	32.82	30.70 B	10.58	23.14
F value[1]	0.83 ns	1.10 ns	4.00**	1.06 ns	0.66 ns
CV (%)	2.66	5.38	3.97	7.49	7.95

Means followed by different letters in the same column are significantly different ($p < 0.05$) by Tukey's test. [1]ns – not significant; **significant ($p < 0.01$). [2]Quadratic effect of phytase levels: $\hat{y} = 30.4581 + 0.0051x – 0.000005x^2$ ($R^2 = 64.97$).

Conclusion

The inclusion of 250 FTU phytase kg^{-1} of feed resulted in similar performance of the broilers that received the control diet with the higher level of dicalcium phosphate; however, above this level, the addition of phytase enzyme determined a linear decrease on bird performance and a negative impact on bone development. The best leg and thigh yield was obtained in 514 FTU phytase kg^{-1} feed level. The availability of nutrients in the commercial product, as indicated by the manufacturer, may have determined these results, suggesting that product nutritional matrix should be reviewed, and the need for further studies with the product.

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