Revista Brasileira de Zootecnia
© 2011 Sociedade Brasileira de Zootecnia
ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.40, n.10, p.2205-2210, 2011

Lysine nutritional requirements of broilers reared in clean and dirty environments during the pre-starter and starter phases

Rodrigo Santana Toledo[1], Horacio Santiago Rostagno[1], Luiz Fernando Teixeira Albino[1], Marli Arena Dionizio[1], Débora Cristine de Oliveira Carvalho[1], Eduardo Terra Nogueira[2]

[1] *Departamento de Zootecnia, UFV, Viçosa – MG.*
[2] *Ajinomoto do Brasil/Ajinomoto Animal Nutrition, São Paulo.*

ABSTRACT - A total of 3,760 Ross male broiler chicks were used in two trials, one in the pre-starter (1-11 days) phase and the other in the starter (12-22 days) phase. Birds were distributed in a completely randomized experimental design with a factorial arrangement of 5 digestible lysine levels × 2 environments (clean and dirty environment), with eight replicates per treatment. The following dietary digestible lysine levels used were: 1.06, 1.12, 1.18, 1.24 and 1.30% in the pre-starter phase, and 1.00, 1.06, 1.12, 1.18 and 1.24% in the starter phase. Minimal relation of digestible lysine:digestible methionine + cystine, threonine, tryptophan and arginine (72, 67, 19 and 108%, respectively) were maintained, as well as 2.088 and 2.002% of glycine+serine in the pre-starter and starter diets, respectively. Weight gain, feed intake and feed conversion were evaluated. In all phases, dietary digestible lysine levels significantly influenced broiler performance, and broilers reared in the clean environment presented better performance than those reared in the dirty environment. The recommended digestible lysine levels during the pre-starter and starter phases are 1.30 and 1.24% when broilers are reared in the clean enviroment and 1.26 and 1.165% in the dirty enviroment, respectively.

Key Words: digestible amino acids, nutritional requirements, performance

Introduction

Genetic improvement programs have selected broilers and pigs for increasing weight gain and feed conversion ratio efficiency. Consequently, the nutritional requirements of these animals have increased. Geraert et al. (2002) demonstrated that lysine requirements of poultry linearly increase as daily weight gain increases. Moreover, lysine is used as the reference amino acid in the formulation of feeds based on the ideal protein concept.

While presenting higher performance efficiency, modern lines of poultry are more sensitive to stressors of pathogenic nature and others, which activate the immune system and lead to lower live performance (McFarlane et al., 1989; Klasing, 1997; Williams et al., 1997).

The objective of the present study was to determine lysine nutritional requirements of male broilers reared in clean or dirty environments during the pre-starter and starter phases.

Material and Methods

The experiments were carried out at the Setor de Avicultura of the Departamento de Zootencia of Universidade Federal de Viçosa (UFV). Birds were housed in a mansonry broiler houses distributed in 1.0 × 2.25-m pens. Wood shavings were used as litter material, and infrared lamps for brooding. Maximum and minimal temperatures were recorded during the entire experimental period as measured by two thermometers placed in different areas of the broiler house. A lighting program of 24 h of natural and artificial light was applied during the entire experimental period.

In the first experiment, lysine nutritional levels for broilers during the pre-starter phase (1-11 days) were determined. A number of 2,000 male Ross chicks, with average initial body weight of 39 g, was distributed in a completely randomized experimental design with a 5 × 2 factorial arrangement of five lysine levels (1.06, 1.12, 1.18, 1.24 or 1.30% digestible lysine) and two types of environment (clean or dirty) with eight replicates of 25 birds each. A level of 2.088 glycine + serine was used in all diets.

Basal diet contained 22.5% crude protein, 2.950 kcal ME/kg and 1.06% digestible lysine. The tested diets were obtained by adding increasing levels of lysine-HCl (0.06%) to the basal diet, maintaining minimum digestible amino acids/digestible lysine ratios of 72% methionine + cystine; 67% threonine; 19% tryptophan and 108% arginine (Table 1).

Received October 6, 2009 and accepted March 11, 2011.
Corresponding author: rstoledo@bol.com.br

Table 1 - Ingredient and chemical compositions and nutritional values of the experimental diets fed during the pre-starter phase to broilers reared in clean and dirty environments (as fed)[1]

	Digestible lysine level (%)				
	1.06	1.12	1.18	1.24	1.30
Corn	36.779	36.779	36.779	36.779	36.779
Soybean meal	33.032	33.032	33.032	33.032	33.032
Low-tannin sorghum	20.000	20.000	20.000	20.000	20.000
Corn gluten meal	4.000	4.000	4.000	4.000	4.000
Oil	1.560	1.560	1.560	1.560	1.560
Dicalcium phosphate	1.889	1.889	1.889	1.889	1.889
Limestone	1.023	1.023	1.023	1.023	1.023
Salt	0.467	0.467	0.467	0.467	0.467
Starch	0.710	0.591	0.448	0.262	0.035
DL-methionine 99%	0.127	0.170	0.215	0.258	0.302
L-lysine HCl 79%	0.098	0.174	0.250	0.326	0.402
L-threonine 98%	—	—	0.022	0.062	0.103
L-arginine 99%	—	—	—	0.027	0.093
Choline chloride 60%	0.100	0.100	0.100	0.100	0.100
Vitamin premix*	0.100	0.100	0.100	0.100	0.100
Mineral premix*	0.050	0.050	0.050	0.050	0.050
Anticoccidial[2]	0.055	0.055	0.055	0.055	0.055
Butyl-hydroxi-toluene	0.010	0.010	0.010	0.010	0.010
	Calculated composition				
Metabolizable energy, kcal/kg	2.950	2.950	2.950	2.950	2.950
Crude protein, %	22.500	22.500	22.500	22.500	22.500
Calcium, %	0.988	0.988	0.988	0.988	0.988
Available phosphorus, %	0.466	0.466	0.466	0.466	0.466
Sodium, %	0.224	0.224	0.224	0.224	0.224
Chlorine, %	0.304	0.304	0.304	0.304	0.304
Potassium, %	0.789	0.789	0.789	0.789	0.789
Total lysine, %	1.170	1.230	1.290	1.350	1.410
Digestible lysine, %	1.060	1.120	1.180	1.240	1.300
Total methionine + cystine, %	0.842	0.886	0.923	0.972	1.020
Digestible methionine + cystine, %	0.763	0.806	0.850	0.893	0.936
Total threonine, %	0.860	0.860	0.882	0.920	0.960
Digestible threonine, %	0.750	0.750	0.791	0.831	0.871
Digestible tryptophan, %	0.241	0.241	0.241	0.241	0.241
Digestible arginine, %	1.312	1.312	1.312	1.339	1.404
Digestible isoleucine, %	0.737	0.737	0.737	0.737	0.737
Digestible valine, %	0.952	0.952	0.952	0.952	0.952
Glycine + serine, %	2.088	2.088	2.088	2.088	2.088

[1] Minimal digestible amino acids/digestible lysine ratios: 72% methionine + cystine; 67% threonine; 19% tryptophan and 108% arginine.
[2] Salinomycin - 66 mg.
* Vitamin A - 10,000 IU; vit. D_3 - 2,000 IU; vit. E - 30 IU; vit. B_1 - 2 mg; vit. B_6 - 3 mg; vit. B_{12} - 0.015 mg; pantothenic acid - 12 mg; biotin - 0.10 mg; vit. K_3 - 3 mg; folic acid - 1.0 mg; nincotinic acid - 50 mg; selenium - 0.25 g; manganese - 106 g; iron - 100 g; copper - 20 mg; cobalt - 2 mg; iodine - 2 mg; zinc - 50 mg.

Average minimum and maximum temperatures recorded were 22.8 ± 0.97 and 34.4 ± 1.85 ^oC, respectively.

In the second experiment, lysine nutritional levels for broilers during the pre-starter phase (12-22 days) were determined. A number of 1,760 male Ross chicks, with average initial weight of 252 g, was distributed in a completely randomized experimental design with a 5 × 2 factorial arrangement of five lysine levels (1.00; 1.06; 1.12; 1.18 and 1.24% digestible lysine) and two types of environment (clean or dirty) with eight replicates of 22 birds each. A level of 2.002 glycine + serine was used in all diets.

Birds in the second experiment were reared in a different environment from 1 to 11 days of age on new wood-shavings litter and fed on a pre-starter diet formulated according to the recommendations of Rostagno et al. (2005). During the experimental period, from 12 to 22 days, the basal diet contained 21.5% crude protein, 3,000 kcal ME/kg and 1.00% digestible lysine. The test diets were composed of the addition of increasing levels of lysine HCl (0.06%), maintaining minimum digestible amino acids/digestible lysine ratios of 72% methionine + cystine; 67% threonine; 19% tryptophan and 108% arginine (Table 2). Average minimum and maximum temperatures recorded were 22.4 ± 1.01 and 32.2 ± 1.96 ^oC, respectively.

In both experiments, the clean environment was washed, disinfected, and a flame gun was used to completely disinfect the environment. New wood shavings were used as litter. On the other hand, the dirty environment was not washed

Table 2 - Ingredients, chemical composition, and nutritional levels of the experimental diets fed during the starter phase in both evaluated environments (as fed)[1]

	Digestible lysine level (%)				
	1.00	1.06	1.12	1.18	1.24
Corn	38.468	38.468	38.468	38.468	38.468
Soybean meal	31.906	31.906	31.906	31.906	31.906
Low-tannin sorghum	20.000	20.000	20.000	20.000	20.000
Corn gluten meal	3.000	3.000	3.000	3.000	3.000
Oil	2.222	2.222	2.222	2.222	2.222
Dicalcium phosphate	1.767	1.767	1.767	1.767	1.767
Limestone	0.984	0.984	0.984	0.984	0.984
Salt	0.448	0.448	0.448	0.448	0.448
Starch	0.710	0.591	0.439	0.267	0.041
DL-methionine 99%	0.114	0.157	0.201	0.245	0.289
L-lysine HCl 79%	0.066	0.142	0.218	0.294	0.370
L-threonine 98%	—	—	0.032	0.074	0.114
L-arginine 99%	—	—	—	0.010	0.076
Choline chloride 60%	0.100	0.100	0.100	0.100	0.100
Vitamin premix*	0.100	0.100	0.100	0.100	0.100
Mineral premix*	0.050	0.050	0.050	0.050	0.050
Anticoccidial[2]	0.055	0.055	0.055	0.055	0.055
Butyl-hydroxi-toluene	0.010	0.010	0.010	0.010	0.010
	Calculated composition				
Metabolizable energy, kcal/kg	3.000	3.000	3.000	3.000	3.000
Crude protein, %	21.500	21.500	21.500	21.500	21.500
Calcium, %	0.939	0.939	0.939	0.939	0.939
Available phosphorus, %	0.441	0.441	0.441	0.441	0.441
Sodium, %	0.216	0.216	0.216	0.216	0.216
Chlorine, %	0.293	0.293	0.293	0.293	0.293
Potassium, %	0.771	0.771	0.771	0.771	0.771
Total lysine, %	1.109	1.169	1.229	1.289	1.349
Digestible lysine, %	1.000	1.060	1.120	1.180	1.240
Total methionine + cystine, %	0.798	0.842	0.885	0.928	0.971
Digestible methionine + cystine, %	0.720	0.763	0.806	0.850	0.893
Total threonine, %	0.824	0.824	0.855	0.896	0.935
Digestible threonine, %	0.718	0.718	0.750	0.791	0.831
Digestible tryptophan, %	0.232	0.232	0.232	0.232	0.232
Digestible arginine, %	1.264	1.264	1.264	1.274	1.339
Digestible isoleucine, %	0.720	0.720	0.720	0.720	0.720
Digestible valine, %	0.909	0.909	0.909	0.909	0.909
Glycine + serine, %	2.002	2.002	2.002	2.002	2.002

[1] Minimal digestible amino acids/digestible lysine ratios: 72% methionine + cystine; 67% threonine; 19% tryptophan and 108% arginine.
[2] Salinomycin - 66 mg.
* Vitamin A - 10,000 IU; vit. D_3 - 2,000 IU; vit. E - 30 IU; vit. B_1 - 2 mg; vit. B_6 - 3 mg; vit. B_{12} - 0.015 mg; pantothenic acid - 12 mg; biotin - 0.10 mg; vit. K_3 - 3 mg; folic acid - 1.0 mg; nincotinic acid - 50 mg; selenium - 0.25 g; manganese - 106 g; iron - 100 g; copper - 20 mg; cobalt - 2 mg; iodine - 2 mg; zinc - 50 mg.

or disinfected, and the litter was a wood-shavings type used for two consecutive flocks, obtained from a commercial farm. No antibiotic growth promoters were used in the diets fed to broilers reared in the clean or dirty environments.

At the end of each experiment, the following performance parameters were evaluated: weight gain, feed intake and feed conversion ratio. Data were submitted to statistical analysis using SAEG statistical package according to Ribeiro Júnior (2001).

Results and Discussion

Values of analyzed crude protein and amino acid were different from those calculated due to differences in their content in the raw materials used, particularly in soybean meal, to analytical variation, and to the fact that the nitrogen value of the added synthetic amino acids was not taken into account in the formulation of the experimental diets; however, the minimal ratios between lysine and the other amino acids were achieved (Table 3).

During the pre-starter phase, broilers reared in the clean environment presented higher weight gain as compared with those reared in the dirty environment ($P<0.05$). However, rearing environment did not influence ($P>0.05$) feed intake or feed conversion ratio (Table 4). There was a linear effect of lysine on the feed intake ($P<0.05$) of broilers reared in both environments and a quadratic effect on the weight gain of those reared in the clean ($P<0.05$) and dirty ($P<0.11$) environments, respectively. This was also observed by Goulart et al. (2008), but on the other

Table 3 - Values of analyzed crude protein and amino acid in the pre-starter diet fed to broilers reared in dirty and clean environments (as fed)

	Digestible lysine level (%)				
	1.06	1.12	1.18	1.24	1.30
			Analyzed values[1]		
Crude protein[2], %	23.76	24.19	24.13	24.07	24.61
Lysine, %	1.188	1.259	1.325	1.385	1.468
Methionine + cystine, %	0.835	0.881	0.883	0.920	0.974
Threonine, %	0.892	0.908	0.951	0.943	0.989

[1] Analysis carried out by Ajinomoto Biolatina.
[2] Crude protein calculation did not take into consideration the N value of the added amino acids.

Table 4 - Effect of digestible lysine dietary level and rearing environment on the performance of broilers during the pre-starter phase (1-11 days of age)

Digestible lysine level (%)	Weight gain (g)		Feed intake (g)		Feed conversion ratio (g/g)	
	Clean	Dirty	Clean	Dirty	Clean	Dirty
1.06	199	189	264	236	1.325	1.248
1.12	203	196	256	242	1.257	1.233
1.18	209	205	251	253	1.201	1.254
1.24	208	201	256	250	1.227	1.229
1.30	202	205	242	258	1.198	1.260
Mean	205A	199B	254	248	1.241	1.245
Regression	Q*	Q**	L*	L**	L***	ns
Requirement	1.197	1.260	1.300	1.300	1.300	1.060
CV (%)	4.53		7.05		5.00	

Means followed by different capital letters in the same row are different by F test (5%).
Q* $Y = -559.51 + 1282.62X - 535,71X^2$ ($R^2 = 0.91$). Quadratic effect ($P<0.05$).
Q** $Y = -395.77 + 951.35X - 376,98X^2$ ($R^2 = 0.90$). Quadratic effect ($P<0.11$).
L* $Y = 340.333 - 73.3333X$ ($R^2 = 0.74$). Linear effect ($P<0.05$).
L** $Y = 145.533 + 86.6667X$ ($R^2 = 0.87$). Linear effect ($P<0.05$).
L*** $Y = 126.43 + 61.67X$ ($R^2 = 0.84$). Linear effect ($P<0.05$).

hand, Toledo et al. (2007) verified a linear reduction in the weight gain and feed intake as digestible lysine levels in the pre-starter diet increased.

Dietary lysine levels linearly influenced ($P<0.05$) feed conversion ratio only of broilers reared in the clean environment (Figure 1), differently from Goulart et al. (2008), who observed a quadratic effect of lysine levels on the feed conversion ratio of pre-starter broilers, and Toledo et al. (2007), who did not find any effect of increasing digestible lysine level on the feed conversion ratio of pre-starter broilers.

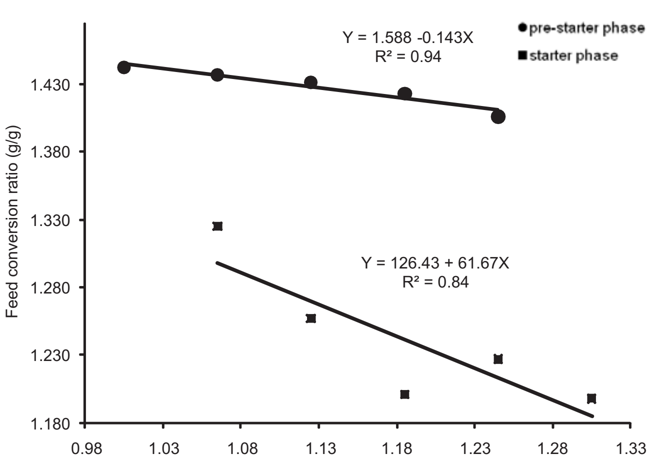

Figure 1 - Effect of dietary digestible lysine level on the feed conversion ratio of broilers reared in a clean environment during the pre-starter and starter phases.

Although the birds reared in the clean environment presented higher weight gain, their digestible lysine nutritional requirement for weight gain was lower than that obtained for the birds reared in the dirty environment. However, the feed conversion ratio of the broilers reared in the dirty environment was not influenced by increasing dietary digestible lysine levels.

The digestible lysine nutritional requirement values of 1.197% and 1.260%, calculated for weight gain of broilers reared in the clean and the dirty environments, respectively, are below those recommended by Rostagno et al. (2005), of 1.285% for the period of 1 to 11 days of age.

As well as in the pre-starter phase, the analyzed crude protein and amino acids levels in the starter diet were different from the calculated levels, but the minimum ratio of lysine to the other amino acids was achieved (Table 5).

During the starter phase (Table 6), broilers reared in the clean environment presented higher weight gain and feed

Table 5 - Values of analyzed crude protein and amino acid in the starter diets fed to broilers reared in dirty and clean environments (as fed)

	Digestible lysine level (%)				
	1.00	1.06	1.12	1.18	1.24
	Analyzed levels[1]				
Crude protein[2], %	23.69	21.86	23.27	23.13	23.77
Lysine, %	1.219	1.118	1.315	1.330	1.465
Methionine + cystine, %	0.813	0.758	0.841	0.857	0.928
Threonine, %	0.884	0.820	0.909	0.919	0.992

[1] Analysis carried out by Ajinomoto Biolatina.
[2] Crude protein calculation did not take into consideration the N value of the added amino acids.

Table 6 - Effect of digestible lysine dietary level and rearing environment on the performance of broilers during the starter phase (12 -22 days of age)

Digestible lysine level (%)	Weight gain (g)		Feed intake (g)		Feed conversion ratio (g/g)	
	Clean	Dirty	Clean	Dirty	Clean	Dirty
1.00	515	509	746	742	1.442	1.456
1.06	524	516	761	730	1.437	1.414
1.12	531	530	760	751	1.431	1.417
1.18	533	524	759	755	1.423	1.428
1.24	538	522	756	744	1.406	1.425
Mean	528A	520B	756A	744B	1.428	1.431
Regression	L*	Q*	ns	ns	L**	Q**
Requirement	1.240	1.158	1.00	1.00	1.24	1.14
CV (%)	2.30		2.20		1.63	

Means followed by different capital letters in the same row are different by F test (5%).
Q* $Y = -483.62 + 1745.56X - 753,97X^2$ ($R^2 = 0.85$). Quadratic effect ($P<0.05$).
Q** $Y = 4.188 - 4.88X + 2.143X^2$ ($R^2 = 0.73$). Quadratic effect ($P<0.05$).
L* $Y = 425.53 + 91.67X$ ($R^2 = 0.95$). Linear effect ($P<0.05$).
L** $Y = 1.588 - 0.143X$ ($R^2 = 0.94$). Linear effect ($P<0.05$).

intake (P<0.05) when compared with those reared in the dirty environment. Feed conversion ratio was not influenced (P>0.05) by the rearing environment.

Digestible lysine levels had a linear influence (P<0.05) in weight gain and feed conversion ratio (Figure 1) of broilers reared in the clean environment, and quadratically affected (P<0.05) these parameters in those reared in the dirty environment. Lana et al. (2005) also observed a linear effect (P<0.05) of digestible lysine levels on weight gain, but did not find any significant effect on feed conversion ratio. On the other hand, feed intake was not affected (P>0.05) by increasing digestible lysine levels, as previously observed by Lana et al. (2005).

The results obtained in the present study with birds reared in the clean environment are contrasting with the findings of Goulart et al. (2008), who observed a linear effect of lysine levels on feed conversion ratio and a quadratic effect on weight gain and feed intake. Campestrini et al. (2010) also found a quadratic effect of lysine on weight gain, but linear effect on feed conversion ratio.

The recommended digestible lysine levels for this phase were 1.24% for broilers reared in the clean environment and 1.158% for those in the dirty environment. The recommended level of 1.24% digestible lysine for broilers reared in the clean environment is higher than those recommended by the NRC (1994), Barboza (2000), Costa et al. (2001), Lana et al. (2005), Rostagno et al. (2005) and Goulart et al. (2008), but below the levels recommended by Campestrini et al. (2010).

Except for the digestible lysine levels recommended by Rostagno et al. (2005) for the pre-starter phase, the digestible lysine levels calculated both for the pre-starter and the starter phases were higher than those recommended by several authors (NRC, 1994; Conhalato, 1999; Barboza, 2000; Costa et al., 2001; Lana et al., 2005, Rostagno et al., 2005; Goulart et al., 2008), which demonstrates the need of continuously updating poultry nutritional requirements due to the intensive genetic improvement of the current commercial broiler lines.

As opposed to the findings of Rostagno & Pack (1995); Han & Baker (1994) and Costa et al. (2001), who found that lysine requirements for feed conversion ratio were always higher than those for weight gain, this was not the case in the present study, except for the lysine requirements of broilers reared in the clean environment during the pre-starter phase.

When performance data of the two evaluated environments were compared, it was observed that broilers reared in the clean environment consistently performed better and had higher digestible lysine requirements than those reared in the dirty environment. Klasing & Barnes (1988) also found worse performance and lower lysine and methionine requirements in broilers whose immune system was stimulated by an environmental challenge.

Roura et al. (1992) found that both acute stimulation by *S. typhimurium* lipopolysaccharide injection and chronic stimulation by a dirty environment of the immune system caused the release of interleukin-1 (IL-1), resulting in worse broiler performance.

Klasing et al. (1987), Klasing & Johnstone (1991), Klasing (1994) and Johnson (1997) reported that immune system stimulation and the consequent release of cytokines, such as interleukins 1 and 6 (IL-1 and IL-6) and tumor-necrosis factor (TNF-a), reduce feed intake and deviate nutrients from growth to the immune system, leading to lower nutritional requirements. The performance data obtained in the present study are consistent with literature data that showed the chronic stimulation of the immune system of broilers reared in dirty environments reduced broiler performance and nutritional requirements.

Conclusions

Digestible lysine nutritional requirements during the pre-starter and starter phases of broilers reared in clean environments are 1.30 and 1.24%, and in dirty environments, 1.26 and 1.165%, respectively.

References

BARBOZA, W.R.; ROSTAGNO, H.S.; ALBINO, L.F.T. et al. Níveis de lisina para frangos de corte de 1 a 21 e 15 a 40 dias de idade. **Revista Brasileira de Zootecnia**, v.29, n.4, p.1082-1090, 2000.

CAMPESTRINI, E.; BARBOSA, M.J.B.; NUNES, R.V. et al. Níveis de lisina digestível com dois balanços eletrolíticos para pintos de corte na fase inicial, de 1 a 21 dias de idade. **Revista Brasileira de Zootecnia**, v.39, n.1, p.151-157, 2010.

CONHALATO, G.S.; DONZELE, J.L.; ROSTAGNO, H.S. et al. Níveis de lisina digestível para pintos de corte machos na fase de 1 a 21 dias de idade. **Revista Brasileira de Zootecnia**, v.28, n.1, p.91-97, 1999.

COSTA, F.G.P.; ROSTAGNO, H.S.; ALBINO, L.F.T. et al. Níveis dietéticos de lisina para frangos de corte nos períodos de 01 a 21 e 22 a 42 dias de idade. **Revista Brasileira de Zootecnia**, v.30, n.5, p.1490-1497, 2001.

GERAERT, P.A.; MANSUY, E.; JAKOB, S. et al. Nutritional concepts to adjust amino acid requirements for poultry. In: EUROPEAN POULTRY CONFERENCE, 11., 2002, Bremen, Germany. **Proceedings...** Bremen, 2002. (CD-ROM).

GOULART, C.C.; COSTA, F.G.P.; LIMA NETO, R.C. et al. Exigência de lisina digestível para frangos de corte machos de 1 a 42 dias de idade. **Revista Brasileira de Zootecnia**, v.37, n.5, p.876-882, 2008.

HAN, Y.; BAKER, D.H. Digestible lysine requeriment of male and female broiler chicks during the period three to six weeks posthatching. **Poultry Science**. v.73, n.10, p.1739-1745. 1994.

JOHNSON, R.W. Inhibition of growth by pro-inflammatory cytokines: an integrated view. **Journal of Animal Science**, v.75, n.6, p.1244-1255, 1997.

KLASING, K.C.; LAURIN, D.E.; PENG, R.K.; et al. Immunologically mediated growth depression in chicks: Influence of feed intake, corticosterone and interleukin-1. **Journal of Nutrition**, v.117, n.7, p.1629-1637, 1987.

KLASING, K.C.; BARNES, D.M. Decreased amino acid requirements of growing chicks due to immunologic stress. **Journal of Nutrition**, v.118, n.10, p.1158-1164. 1988.

KLASING, K.C.; JOHNSTONE, B.J. Monokines in growth and development. **Poultry Science**, v.70, n.10, p.1781-1789, 1991.

KLASING, K.C. Avian leukocytic cytoquines. **Poultry Science**, v.73, n.8, p.1035-1043, 1994.

KLASING, K.C. Interactions between nutrition and infectious disease. In: CALNEK, B.W. (Ed.) **Diseases of poultry**. Ames: Iowa University Press. 10.ed. 1997. 1080p.

LANA, S.R.V.; OLIVEIRA, R.F.M.; DONZELE, J.L. et al. Níveis de lisina digestível em rações para frangos de corte de 1 a 21 dias de idade mantidos em ambiente de termoneutralidade. **Revista Brasileira de Zootecnia**, v.34, n.5, p.1614-1623, 2005.

McFARLANE, J.M.; CURTIS, S.E.; SHANKS, R.D. et al. Multiple concurrent stressors in chicks. 1. Effect on weight gain, feed intake, and behavior. **Poultry Science**, v.68, n.4, p.501-509, 1989a.

McFARLANE, J.M.; CURTIS, S.E.; SIMON, J. et al. Multiple concurrent stressors in chicks. 2. Effect on hematologic, body composition and pathologic traits. **Poultry Science**, v.68, n.4, p.510-521, 1989b.

McFARLANE, J.M.; CURTIS, S.E. Multiple concurrent stressors in chicks. 2. Effect on plasma corticosterone and heterophil: lymphocyte ratio. **Poultry Science**, v.68, n.4, p.522-527, 1989b.

NATIONAL RESEARCH COUNCIL - NRC. **Nutrients requirements of poultry**. 9.ed. National Academic Press, Washington, D.C.: 1994. 155p.

RIBEIRO JÚNIOR, J.I. **Análises estatísticas no SAEG**. Viçosa, MG: Folha de Viçosa, 2001. 301p.

ROSTAGNO, H.S.; PACK, M. Growth and breast meat responses of different broiler strains to dietary lysine. In: EUROPEAN SYMPOSIUM OF POULTRY NUTRITION, 10., 1995, Antalya, Turkey. **Proceedings...** Antalya, 1995. p.260-262.

ROSTAGNO, H.S.; ALBINO, L.F.T.; DONZELE, J.L. Tabelas Brasileiras para Aves e Suínos: composição de alimentos e exigências nutricionais. Viçosa, MG: 2005. 186p.

ROURA, E.; HOMEDES, J.; KLASING, K.C. Prevention of immunologic stress contributes to the growth-permitting ability of dietary antibiotics in chicks. **Journal of Nutrition**, v.122, n.12, p.2383-2390, 1992.

TOLEDO, A.L.; TAKEARA, P.; BITTENCOURT, L.C. et al. Níveis dietéticos de lisina digestível para frangos de corte machos no período de 1 a 11 dias de idade: desempenho e composição corporal. **Revista Brasileira de Zootecnia**, v.36, n.4, p.1090-1096, 2007 (supl.).

WILLIAMS, N.H.; STAHLY, T.S.; ZIMMERMAN, D.R. Effect of chronic immune system activation on the rate, efficiency, and composition of growth and lysine needs of pigs fed from 6 to 27 kg. **Journal of Animal Science**, v.75, n.12, p.2463-2471a.

WILLIAMS, N.H.; STAHLY, T.S.; ZIMMERMAN, D.R. Effect of chronic immune system activation on the rate, efficiency, and composition of growth and lysine needs of pigs fed from 6 to 111 kg. **Journal of Animal Science**, v.75, n.12, p.2481-2496b.