Nutrient requirements of broilers for optimum growth and lean mass

H. ROSTAGNO[1*], L. PÁEZ[1], and L. ALBINO[1]

[1]Departamento de Zootecnia, [2]Universidade Federal de Viçosa, 36570-000 - Viçosa – MG – Brazil.
* rostagno@ufv.br

Abstract: To take advantage from genetic improvement of broiler chickens, updates must be made of the nutritional levels that promote maximum protein accretion and minimum fat deposition. The development of growth models is a valuable tool to understand nutrient deposition in poultry. This article presents experimental results and methodologies used to obtain prediction equations for true digestible lysine requirements, based on performance; however, higher dietary lysine levels are needed to minimize abdominal fat deposition. Feed conversion ratio is the most commonly used parameter to determine broiler nutritional requirements. Methionine + cystine and threonine requirements determined by feed conversion ratio optimize carcass parameters. The reduction of protein level in broiler diets does not affect performance or breast fillet yield, but linearly increases abdominal fat deposition. Further studies need to be carried out aiming at reducing the variation of the parameters used to evaluate broiler carcasses.

Key Words: Broilers; lean mass; requirements; amino acids

Introduction

Broiler production is currently oriented for parts marketing, and no longer to whole carcasses, which led to the development of birds with higher lean tissue yield and lower fat content (Buteri, 2003). Carcass fat content is one of the main concerns of poultry companies as the increasing awareness of consumers on health problems has generated rejection of fat carcasses. In addition to genetics, lean tissue accretion and fat deposition are influenced by nutrition, feeding program, age, sex, and environmental conditions (Leeson, 1995).

This article uses the recent recommendations of the Brazilian Tables for Poultry and Swine (Rostagno et al., 2005), and discusses nutritional levels to optimize lean tissue accretion and consequent reduction of fat deposition.

Nutritional requirement of lysine

Due to the constant improvement of performance and parts yield of the modern commercial broiler, nutritional requirements need to be updated, particularly lysine, which is used almost exclusively to synthesize protein (meat).

An increase in lysine requirements is observed when results of two performance trials, using 22 to 40-day-old male Ross broilers, are compared. In the study of Barboza (1997), weight at 40 days of age was 1985g, and breast fillet yield, expressed as carcass percentage, was 21.6%. In a more recent experiment (Costa et al., 2001), weight at 40 days of age was 2212g, and breast fillet yield was 24.8%. Due to better broiler performance, digestible lysine requirement increased (0.89% vs. 1.06%).

The lysine requirement, as a percentage of the diet, is influenced not only by bird age or growing phase (e.g., starter vs. grower), but differences in weight gain, feed conversion ratio, and protein and fat deposition rate have a strong impact on broiler nutritional requirements. Based on these evidences,

and using the results of studies carried out at the Federal University of Viçosa (UFV), an equation was developed to calculate true digestible lysine requirement / kg live weight (14.28 + 2.0439 x average weight, R^2= 0.81). Feed conversion ratio results of 30 dose-response experiments with broilers were compiled – six with females and 24 with males – and daily intake of digestible lysine were determined. Then, lysine requirement for maintenance (0.1 $W^{0.75}$) was calculated, and the amount of digestible lysine required per kilo of weight gain was obtained for the different growing phases (Rostagno et al. 2005).

The equation to estimate true digestible lysine requirements for male and female broilers as a function of performance is presented in *Table 1*. The use of the equation to estimate true digestible lysine needs allows flexibility, because there is not a single requirement, but many as a function of performance and feed intake. This prevents excessive nutrient feeding, thereby lowering costs and environmental contamination, as well as deficiencies that may cause productivity losses. Table 1 also presents examples of lysine requirements in g/day for male broilers with different performances (below average, standard and high) for the period of 22 to 33 days of age. Lysine percentage is calculated taking into account daily feed intake.

Table 1 – Digestible lysine requirements of male broilers with different performances (22 to 33 days of age) as calculated by the equation of Rostagno et al. (2005).

Dig. Lys (g/day) = 0.1 x $W^{0.75}$ + (14.28 + 2.0439 x W) x G

W = average body weight in kg**;** **G**= weight gain / day in kg

Performance	**Below Average**	**Standard**	**High**
Average Weight, kg	1.250	1.330	1.438
Weight Gain, kg/day	0,0741	0,0776	0,0824
Feed Intake, kg/day	130.2	134.5	141.0
Dig. Lys Req., g/day	1.366	1.443	1.550
Dig. Lys in Diet, %	1.049	1.073	1.099

Daily requirement of digestible lysine for maintenance = 0.1 x $W^{0.75}$

Since the Brazilian Tables were published in 2005, several experiments were carried out to improve the estimates of true digestible lysine requirement. The trials used male and female Cobb broilers, as this genetic line has been increasingly raised in Brazil and Latin America. Experimental data of Páez (2007) from three different phases (10-21, 22-35, and 37-49 days) are shown in *Table 2*. When the lysine requirements obtained in these experiments are compared with those calculated using the equation of Rostagno et al. (2005), in average, the values are similar. The largest discrepancy was for 31 to 49-day-old males, where the calculated value obtained with the equation show a clear trend to overestimate the lysine requirement, probably due to the excellent daily weight gain (100 g/day) of broiler males during this phase (*Table 2*).

The experiment carried out by Brito (2006), which was part of his Ph.D. thesis, first evaluated protein, fat, and lysine deposition in female and male Ross broilers in the period of 1 to 42 days of age. The author used Gompertz's equation to calculate the amount of each nutrient deposited per kg of weight gain. Carcass protein deposition per kg of weight gain of broiler males increased continuously; however, for females, the maximum point was reached at 28 days. Similar results were obtained for digestible lysine per kg weight gain, with a quadratic response for both sexes. When the values of g of digestible lysine per kg weight gain obtained by Brito (2006) were compared to the equation of the Brazilian Tables (2005), the highest differences were observed in the pre-starter phase, that is, during the first days of life. As for the remaining phases, data are similar, except for the discrepancy with 42-day-old females, indicating that protein and digestible lysine levels per kg of weight gain show a quadratic response with live weight.

Lysine level and carcass quality

According to Geraert et al. (2005), amino acid requirements for broilers have been historically determined in dose-response trials, with the concentration of the amino acid that produces maximum

weight gain chosen as the requirement. However, recommended dietary amino acid levels may vary according to performance and carcass parameters. In general, lysine requirement hierarchy, as mentioned by Leclercq (1998), would follow the following order: weight gain <breast fillet<feed conversion ratio<abdominal fat.

Table 2 – True digestible lysine requirements (Lys) of male (M) and female (F) Cobb broilers for optimal feed conversion ratio (Páez, 2007).

Age 10 – 21 days			Age 22 – 35 days			Age 37 – 49 days		
Lys %	**M**	**F**	**Lys %**	**M**	**F**	**Lys %**	**M**	**F**
1.06	1.48[1]	1.50[1]	0.92	1.77[1]	1.81[1]	0.84	2.12[1]	2.24[1]
1.12	1.47	1.47*	0.98	1.72	1.80	0.90	2.05	2.20
1.16	1.43*	1.46	1.04	1.69*	1.78	0.96	2.02*	2.18*
1.24	1.46	1.47	1.10	1.73	1.76*	1.02	2.03	2.18
1.30	1.44	1.46	1.16	1.72	Nd	1.08	2.02	2.17
Gain, g/day*	53.5	47.9		95.2	81.0		100.0	78.1
Dig. Lys Req.* %	1.16	1.12		1.04	1.10		0.96	0.96
g Dig. Lys/kg Gain*	15.5	15.3		16.3	17.6		17.5	18.6
Dig. Lys Intake g/day*	0.888	0.789		1.675	1.538		1.957	1.633
Dig. Lys Req.% (UFV)	1.13	1.12		1.04	1.03		1.07	0.97
g Lys/kg Gain (UFV)	15.3	15.2		17.0	16.7		19.7	18.8
Cons. Lys g/day (UFV)	0.867	0.793		1.744	1.468		2.174	1.649

1. Feed conversion ratio. * Best level UFV = equation of Rostagno et al. (2005).

In order to study the effect of dietary digestible lysine level, while maintaining a constant amino acid to lysine ratio, on lysine and abdominal fat deposition, Paez (2007) carried out an experiment with Cobb broilers during the period of 10 to 21 days of age. *Table 3* shows the experimental results, demonstrating that male birds linearly increased lysine body deposition, whereas females presented a quadratic response. In the starter phase, considering only lysine deposition, digestible lysine requirements of males was higher than females (1.30 vs. 1.22%); however, when abdominal fat deposition is taken into account, the situation is reversed, with females linearly decreasing far deposition. During this phase, recommended levels of digestible lysine for male and female Cobb broilers is 1.30%. This value is 12% and 14% higher than those recommended in *Table 2* for digestible lysine for optimal feed conversion ratio for males and females, respectively.

Table 3 – Effect of dietary digestible lysine level on lysine and fat deposition of Cobb broilers, from 10 to 21 days of age (Páez, 2007).

Dig. Lys level (%)	Lysine Deposition (g/bird/day)		Fat Deposition (g/bird/day)	
	Males	**Females**	**Males**	**Females**
1.06	0.580	0.505	5.61	6.55
1.12	0.538	0.508	6.26	6.31
1.18	0.601	0.533	6.04	5.72
1.24	0.593	0.514	5.12	5.69
1.30	0.627	0.458	6.02	5.37
Mean	0.588 A	0.503 B	5.81	5.93
Regression	L	Q	Ns	L
requirement (%)[1]	1.30	1.22	1.06	1.30
CV (%)	3.37		9.79	

1.- digestible lysine requirement for optimal feed conversion ratio: Males, 1.16%; Females, 1.12%. (*Table 23*).

An experiment performed by Barboza et al. (2001) evaluated performance and carcass parameters of two broiler strains (Hubbard and Ross) fed different dietary levels of total lysine. The regression analysis for breast fillet data showed that Ross males and females, in addition to producing more breast meat, also had higher total lysine requirements as compared to Hubbard birds. For abdominal fat, males of both lines presented different lysine requirements, with 1.125% for Ross and 1.050% for Hubbard. Females from both strains presented a linear reduction of abdominal fat as dietary lysine increased. This experiment clearly showed that the improvement in breast meat yield resulted in increased lysine requirement, and that the lysine level needed to minimize abdominal fat deposition is higher than for breast meat accretion, particularly in females (*Table 4*).

Table 4 – Effect of total lysine level on breast meat yield and abdominal fat deposition (%) of male and female broilers of two commercial genetic lines, during the period of 15 to 40 days of age.

Total lysine level (%)	Breast fillet (%)				Abdominal fat (%)			
	Ross		Hubbard		Ross		Hubbard	
	M	F	M	F	M	F	M	F
0.825	18.6	19.9	17.4	18.3	2.8	3.1	2.7	2.6
0.885	20.7	21.3	19.0	19.6	2.5	2.8	2.3	2.5
0.945	22.1	22.7	19.7	20.2	2.6	2.8	2.1	2.5
1.005	22.8	22.5	21.0	21.0	2.3	2.4	2.0	2.4
1.065	23.5	22.9	20.8	20.6	2.4	2.7	2.1	2.2
1.125	23.6	23.3	20.5	21.0	2.3	2.6	2.0	2.1
Mean	21.9	22.1	19.7	20.1	2.5	2.7	2.2	2.4
Regression	Q	Q	Q	Q	L	L	Q	L
Requirement, %	1.102	1.083	1.058	1.074	1.125	1.125	1.050	1.125
CV (%)	3.20				9.75			

1. Total lysine requirement for optimal feed conversion ratio: Ross, 1.089% (males) and 1.125% (females); Hubbard, 1.082 (males) and 1.125 (females). Barboza et al (2001).

Páez (2007) carried out an experiment to estimate dietary digestible lysine requirement, maintaining a constant amino acid to lysine ratio, of 22- to 35-day-old Cobb broilers. Table 5 shows a linear effect of digestible lysine levels on male breast fillet yield, or 1.16% digestible lysine level for maximum fillet yield. This level is higher than the requirement of 1.04% digestible lysine for optimal feed conversion ratio (*Table 2*), suggesting a higher digestible lysine requirement to maximize breast meat yield. Again, abdominal fat percentage in the carcass of males was not influenced by dietary lysine, which is consistent with the results of fat deposition during the period of 10 a 21 days of age. Females also responded linearly to lysine in terms of breast fillet yield, and differently from males, there was a significant effect on abdominal fat percentage. Therefore, the level recommended for maximal breast fillet yield and minimal abdominal fat percentage in the carcass is 1.16% digestible lysine of (*Table 5*).

Methionine + Cystine and carcass quality

Shuttle e Pack (1995), using Ross broilers during the phases of 15 to 34 and of 14 to 38 days of age, concluded that total methionine + cystine levels for optimal feed conversion ratio and breast yield was 0.88% (0.78% true digestibility). The requirement for weight gain was lower than the other parameters, suggesting a hierarchy in methionine + cystine requirements.

The recommendations of Rostagno et al (2005) for digestible methionine + cystine to digestible lysine (71 – 72%) were based on the results of three experiments with male Ross broilers carried out by Tejedor (2002). Recently, Paez (2007) carried out experiments to update digestible methionine + cystine to digestible lysine ratio in male and female Cobb broilers. The researcher evaluated

performance and carcass parameters, as well as body protein accretion during the period to 22 a 35 days of age. Using regression analysis, the best feed conversion ratio was obtained with a digestible methionine + cystine to digestible lysine ratio of 75.7% for males and 81.5% for females. Both sexes presented a linear response for protein accretion, and a maximum ratio of 79.6% and 83.1%, respectively. For breast fillet yield and abdominal fat, the recommended methionine + cystine levels were lower than those for feed conversion ratio and protein accretion (*Table 6*).

Table 5 – Effect of digestible lysine levels on carcass parameters of Cobb broilers during the grower phase (22-35 d). (Páez, 2007)

Digestible Lysine (%)	Breast Fillet (%)		Abdominal Fat (%)	
	Males	Females	Males	Females
0.92	23.8	23.7	1.33	1.91
0.98	24.2	23.8	1.37	1.62
1.04	24.0	24.7	1.47	1.45
1.10	24.5	24.9	1.32	1.52
1.16	25.6	24.8	1.24	1.39
Mean	24.4	24.3	1.34 B	1.58 A
Regression	L	L	ns	L
Requirement (%)	1.16	1.16	----	1.16
CV (%)	4.82		22.38	

1.- Digestible lysine requirement for optimal feed conversion ratio: Males, 1.04%; Females, 1.10% (*Table 2*).

Table 6 – Effect of digestible methionine + cystine to digestible lysine ratio on performance and carcass parameters of male and female Cobb broilers from 22 to 35 days of age. (Paez, 2007).

M+C / Lys Ratio (%)[1]	Feed Conversion	Breast Fillet (%)	Abdominal Fat (%)	Protein Accretion (g/bird/day)
Males				
64.1	1.788	23.74	1.51	12.31
66.6	1.742	24.14	1.25	12.44
72.1	1.690	24.05	1.40	12.82
77.7	1.690	24.26	1.52	12.12
79.6	1.689	24.38	1.24	16.32
Regression	Q	Ns	ns	L
M+C/ Lys	75.7 %	64.1%	64.1%	79.6%
Females				
65.7	1.956	23.18	1.98	8.29
72.1	1.903	23.66	1.74	10.19
73.5	1.858	24.24	1.41	9.24
80.6	1.854	24.33	1.51	9.82
83.1	1.847	23.92	1.62	10.31
Regression	Q	Q	Q	L
M+C/ Lys	81.5 %	77.3%	78.9%	83.1
CV (%)	1.61	3.58	19.48	13.70

dig. M+C / dig. Lys ratio. Dietary dig. Lys: 0.992 % (Males), 0.887 % (Females).

Threonine and carcass quality

In an experiment carried out by Kidd and Kerr (1997), the response of male Ross broilers to increasing total threonine level was evaluated during the period of 30 to 42 days of age. Results showed total threonine levels of 0.65, 0.65, and 0.75% for optimal weight gain, feed efficiency, and breast fillet weight, respectively. This again demonstrates different requirements for different parameters, with higher requirement for fillet gain as compared to the performance variables (weight gain and feed conversion ratio). However, studies by Lecrecq (1998) and Mack et al. (1999) showed similar threonine requirements for breast yield and feed conversion ratio.

It must be noted that the ratio between amino acids and lysine is influenced by factors other than age, and it can also change according to environmental conditions. Kidd et al. (2003), evaluating the response to threonine of male Cobb broilers reared in clean or dirty environments, obtained a quadratic response for performance parameters and breast fillet weight when birds were maintained in the clean environment. However, in the dirty environment, birds had a linear positive response to threonine levels in terms of performance and carcass traits. A possible explanation for the response of the birds in the dirty environment to high threonine levels may be an increase in threonine requirements for gastrointestinal functions.

Páez et al. (2004) studied the performance of male Ross broilers fed three digestible threonine to digestible lysine ratios (60, 65, and 70%), during the period of 1 to 45 days of age. Table 7 shows that higher threonine levels resulted in significant differences in weight gain, feed conversion ratio, and breast fillet weight, and that the 65% ratio was sufficient to maximize all the parameters evaluated.

Table 7 . Effect of digestible threonine to digestible lysine ratio on performance, breast meat yield and abdominal fat of 1 to 45-day-old male broilers (Páez et al., 2004).

Thr/Lys Ratio (%)	Weight Gain (g/bird)	Feed Conversion ratio (g/g)	Breast Fillet (g/bird)	Abdominal Fat (g/bird)
60	2711 ^{B}	1.822 ^{B}	494.5 ^{B}	46.7
65	2731 ^{AB}	1.802 ^{A}	508.1 ^{A}	47.1
70	2742 ^{A}	1.803 ^{A}	508.2 ^{A}	46.0
CV (%)	1.82	1.88	5.33	17.55

6.- Crude protein and carcass quality

Experiments carried out at the Federal University of Viçosa during the 1980s and recently repeated, applying the ideal protein concept, demonstrated the possibility of decreasing dietary protein levels with no effect on broiler weight gain and feed conversion ratio. These studies allowed the recommendation of minimal practical levels of crude protein for male and female broilers (Rostagno et al., 2005).

The present recommendation for the application of the of ideal protein concept in poultry diets is to reduce protein levels, thereby eliminating amino acids excess, both essential and non-essential, and supplement synthetic amino acids, such as lysine, methionine, threonine, and tryptophan, as needed. Two trials were carried out with Ross broilers to study the effect of decreasing dietary protein, while maintaining adequate essential amino acid levels, on breast meat yield and abdominal fat. In the experiment of Costa (2000), there was no significant effect on carcass and high-value parts yields. However, abdominal fat linearly responded to dietary protein levels, showing that carcass fat content decreased as feed protein levels increased. Similar results were found by Toledo (2004), who showed the effect of increasing dietary protein levels on carcass fat content. Moreover, in both experiments, there was no response of breast fillet yield to increasing dietary protein (*Table 8*).

According to MacLeod (1997), the catabolism of amino acids have a high energy cost for the bird. High protein diets may have lower net energy content, and this would explain the decreased fat deposition in the carcass of broilers. Further studies are needed on ideal protein because, as shown in females, the lysine requirement for lower abdominal fat is higher than for other parameters. Other factors also need to be studied, such as the ratio between essential and non-essential amino acids, which can be critical in low-protein diets for broilers.

Table 8. Effect of crude protein level on breast fillet and abdominal fat yield of Ross broilers (Costa et al., 2001 and Toledo, 2004)

Protein (%)	Costa et al. (2001) 22-42 days				Protein (%)	Toledo (2004) 22-35 days	
	Breast Fillet (%)		Ab. Fat (%)			Breast Fillet (%)	Ab. Fat (%)
	M	F	M	F		M	M
17.5	23.10	23.46	3.19	3.47	16	23.61	1.86
18.0	23.49	23.21	2.81	3.58	17	24.57	1.91
18.5	23.05	23.47	3.19	3.85	18	24.72	1.85
19.0	23.29	23.30	3.02	3.15	19	24.33	1.61
19.5	22.88	24.16	2.74	3.20	20	24.59	1.66
Regression	ns	ns	L	L		Ns	L
Requirement	16	16	19.5	19.5		16	20
CV (%)	3.73		9.17			4.74	16.55

M= Males; F= Females.

Coefficient of variation of the parameters

The variation among experimental units, independent of the effect of treatments, is known as experimental error. Increasing the number of animals in the experimental units, as well as the number of replicates, aims at reducing the experimental error.

In order to estimate the experimental variation, one of the measures used by researchers is the coefficient of variation (CV), which represents the standard deviation expressed as a percentage of the mean. This is important because the CV shows the precision of the experiment, and allows the comparison among different parameters and other trials. Table 9 shows the mean coefficients of variation of different parameters used to estimate nutritional requirements in five Theses from the Federal University of Viçosa. Feed conversion ratio presented the lowest coefficient of variation, whereas carcass parameters had the highest. The coefficient of variation for abdominal fat was very high; suggesting that for nutritional level studies aiming at improving breast fillet yield and reducing abdominal fat, the number of replicates and birds per replicate must be increased in order to allow the detection of differences among experimental treatments.

Table 9. Coefficient of variation (%) of different parameters used to determine nutritional requirements of broilers during grower-finisher phase.

Parameter	CV (%)
Weight Gain	3.3 (1.8 – 4.7)[1]
Feed Conversion	2.5 (1.6 – 4.3)
Breast Fillet	3.6 (3.2 – 4.8)
Abdominal Fat	14.5 (9.2 – 22.4)

Mean values of 5 UFV Theses. 1.- CV value (minimum and maximum).

Final considerations

The use of equations to estimate true digestible lysine requirement allows adjustments as a function of broiler performance; however, higher dietary lysine levels are needed to minimize abdominal fat.

Broiler chicken lines with high breast yield and low feed conversion have higher lysine requirements.

Feed conversion ratio is the most commonly used parameter to determine broiler nutritional requirements. Methionine + cystine and threonine requirements determined by feed conversion ratio optimize carcass parameters.

The reduction of protein level in broiler diets does not affect performance or breast fillet yield, but linearly increases abdominal fat deposition.

Further studies need to be carried out to reduce the variation in the parameters used to evaluate broiler carcasses.

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