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ANIMAL PRODUCTION

Dietary supplementation of glutamine and glutamic acid on performance, intestinal morphometry, and carcass characteristics of broiler quails

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ABSTRACT: This study evaluated the effect of dietary supplementation with glutamine and glutamic acid (Gln+Glu) on performance, intestinal morphometry, and carcass characteristics of broiler quails. Eight hundred birds were used, distributed in an entirely randomized design with 20 birds per experimental unit, and given five treatments (0.0; 0.2; 0.4; 0.6; and 0.8% Gln+Glu supplementation) with eight replicates. At 1–21 days of age, lower ($P < 0.05$) feed intake at 0.6 and 0.8% Gln+Glu supplementation and lower weight gain at 0.8% Gln+Glu supplementation compared to the control treatment were observed. By regression analysis, excluding the control treatment, there was an increasing linear effect ($P < 0.05$) for feed intake at 22 to 42 days of age. For intestinal morphometry, Gln+Glu supplementation only favored the villus development of the ileum ($P < 0.05$), giving it greater height at 0.2, 0.6, and 0.8% supplementation. Carcass characteristics, cuts, and edible viscera of the birds at 42 days were not affected ($P > 0.05$) by Gln+Glu supplementation levels. Thus, the glutamine and glutamic acid supplementation affected the performance and intestinal morphology of 21-d-old quails, decreasing feed intake and weight gain associated with the improvement of ileum morphology; conversely, performance and carcass characteristics at 42 days were not affected by amino acid supplementation.
Key words: *Coturnix*, glutamate, intestinal morphophysiology, cell renewal.

Suplementação dietética de glutamina e ácido glutâmico sobre o desempenho, morfometria intestinal e características de carcaça de codornas de corte

RESUMO: Objetivou-se avaliar o efeito da suplementação dietética de glutamina e ácido glutâmico (Gln+Glu) sobre o desempenho, a morfometria intestinal e as características de carcaça de codornas de corte. Foram utilizadas 800 aves, distribuídas em delineamento inteiramente casualizado, com cinco tratamentos (0,0; 0,2; 0,4; 0,6 e 0,8% de suplementação de Gln+Glu) e oito repetições com 20 aves por unidade experimental. Na fase de um a 21 dias, constatou-se menor ($P < 0,05$) consumo de ração aos níveis de 0,6 e 0,8% de Gln+Glu e menor ganho de peso ao nível 0,8% de Gln+Glu em comparação ao tratamento controle; e, pela análise de regressão, excluindo-se o tratamento controle, houve efeito linear crescente ($P < 0,05$) para consumo de ração na fase 22 a 42 dias de idade. Para morfometria intestinal, a suplementação de Gln+Glu apenas favoreceu o desenvolvimento vilos do íleo ($P < 0,05$), conferindo-lhe maior altura aos níveis de 0,2; 0,6 e 0,8% de suplementação. As características de carcaça, cortes e vísceras comestíveis das aves aos 42 dias não foram afetadas ($P > 0,05$) pelos níveis de suplementação de Gln+Glu. Assim, a suplementação de glutamina e ácido glutâmico influenciou o desempenho e a morfometria intestinal de codornas de corte aos 21 dias de idade, promovendo redução do consumo de ração e do ganho, associado ao aumento morfométrico do íleo; por outro lado, o desempenho das aves e as suas características de carcaça aos 42 dias não foram afetados pela suplementação dos aminoácidos.
Palavras-chave: *Coturnix coturnix*, glutamato, morfofisiologia intestinal, renovação celular.

INTRODUCTION

The immaturity of the digestive tract in the first weeks post-hatch is a limiting factor for the development of productive poultry. This is because increases in enzyme secretion capacity and absorption area, which occur through the longitudinal growth of the small intestine and the increase in villus height, remain ongoing (CRUZ et al., 2019; CASTRO et al., 2020). Studies have been developed with the purpose of maximizing the functional capacity of the poultry intestine, using nutrients that can improve the development of the mucosa (DAI et al., 2011; SAKAMOTO et al., 2011; REZAEI et al., 2018), so that there is better utilization of the diet.

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Glutamine, glutamic acid, and threonine are nutrients that have shown important trophic effects on the intestinal mucosa of birds, acting on their development and histological maturation (CASTRO et al., 2020; SALMANZADEH et al., 2016). Among these amino acids, glutamine (Gln) and glutamic acid (Glu) have drawn attention for their functional properties on the intestinal mucosa. Glutamine and glutamic acid are important sources of energy for rapidly proliferating cells, such as enterocytes and defense cells. As trophic agents, they contribute to the development and maintenance of the mucosal structure (FASINA et al., 2010), acting directly on the improvement of poultry performance. Research with broilers and layers has shown satisfactory results regarding the effect of glutamine and glutamic acid supplementation on the performance, digestibility and intestinal microbiota of broilers (NASCIMENTO et al., 2014; BEZERRA et al., 2015; SALMANZADEH et al., 2016); however, studies are needed to evaluate the effect on bird growth and utilization of dietary nutrients in quails.

This study evaluated the effect of dietary glutamine supplementation associated with glutamic acid on the performance, intestinal morphometry, and carcass characteristics of broiler quails.

MATERIALS AND METHODS

A total of 800 unsexed broiler quails were used from 1 to 42 days of age, with a mean initial weight of 9.35 g ± 0.10 g. On the first day, the birds were weighed individually, separated by weight and distributed uniformly by weight range in 40 experimental units.

The experimental design was entirely randomized using 20 birds per experimental unit, with five levels (0.0; 0.2; 0.4; 0.6; and 0.8%) of glutamine supplementation associated with glutamic acid, with eight replicates.

The experimental diets were isonutritive, formulated based on a corn and soybean meal and meeting the nutritional requirements of broiler quails (SILVA & COSTA, 2009) (Table 1). Dietary supplementation of glutamine associated with glutamic acid was performed until 21 days of age of the birds, and from 22 to 42 days of age all birds received the same basal diet. The birds received water and food during the entire rearing period. Weight gain, feed consumption, and feed conversion were evaluated for birds from 1 to 21, 22 to 42, and 1 to 42 days of age. Mortality was monitored daily to calculate rearing viability and to correct feed consumption and feed conversion.

At 21 days of age, five birds per treatment, with an average weight of the experimental unit (± 5%), were removed for evaluation of intestinal morphometry. After stunning by electroscalding followed by bleeding, the median region of the duodenum, jejunum, and ileum was collected to measure villus height, crypt depth, and villus:crypt ratio. The samples were kept in 10% buffered formaldehyde solution for 24 hours, then dehydrated in an increasing series of alcohols, treated with xylene; and subsequently, embedded in paraffin. To mount the slides, cuts 5 µm thick were made with the aid of a rotating microtome. Subsequently, the sections were deparaffinized and hydrated using xylene, a series of alcohols and water, and then stained using the hematoxylin-eosin (HE) method.

Image capture of histological sections was performed using an optical microscope with a 4× magnification lens. The morphometric analyses were performed on an image analyzer (Motic Images Plus 2.0), performing 12 measurements of villus height and 12 measurements for crypt depth per histological section, totaling 60 readings per variable, per treatment, for each intestinal segment.

At 42 days of age, 2 birds per experimental unit, varying by up to 5% from the average weight of the experimental unit, were selected and slaughtered for determination of carcass yield. After manual plucking, the carcasses were eviscerated, washed, drained, and weighed. The weight of the cleaned carcass as a percentage of the live weight of the bird after fasting was considered as the carcass yield. Subsequently, the carcass was dressed and the cuts and viscera were weighed. The yield of legs, breast, wings, back, and edible viscera were considered in relation to the weight of the eviscerated and cleaned carcass.

The results were subjected to an analysis of variance, then compared using Dunnett's post hoc test and regression, with the aid of the statistical program SAS - Statistical Analysis System 9.0 at 5% probability.

RESULTS

The levels of glutamine associated with glutamic acid influenced the performance of the quails, as presented in table 2. Dunnett's test revealed that from 1 to 21 days of age, there was a significant effect ($P < 0.05$) of Gln+Glu supplementation on feed consumption, which was lower at 0.6 and 0.8% Gln+Glu; and on the weight gain of the birds, which also decreased at 0.8% Gln+Glu supplementation, compared to the control treatment. However, the

Table 1 - Percentage and nutritional composition of experimental diets from 1 to 21 days of age.

Ingredients	---Treatments--------------------------------------				
	T1	T2	T3	T4	T5
Glutamine + glutamic acid[a]	0.000	0.200	0.400	0.600	0.800
Maize (7.88%)	48.483	49.349	50.212	51.077	51.942
Soybean meal (45.22%)	45.743	44.106	42.469	40.831	39.194
Soybean oil	2.258	1.923	1.588	1.253	0.917
Dicalcium phosphate (20%)	0.786	0.802	0.818	0.834	0.850
Calcareous limestone	1.446	1.445	1.445	1.445	1.445
Common salt	0.381	0.381	0.382	0.382	0.382
DL-Methionine (99%)	0.390	0.407	0.423	0.439	0.456
L-Lysine HCl (78%)	0.130	0.181	0.232	0.284	0.335
L-Threonine (99%)	0.194	0.218	0.241	0.265	0.289
Choline chloride (60%)	0.070	0.070	0.070	0.070	0.070
Vitamin Premix[b]	0.025	0.025	0.025	0.025	0.025
Mineral Premix[c]	0.050	0.050	0.050	0.050	0.050
Antioxidant (BHT)	0.010	0.010	0.010	0.010	0.010
Growth promoter (Avilamycin)	0.015	0.015	0.015	0.015	0.015
Anticoccidial (Monesin)	0.020	0.020	0.020	0.020	0.020
Inert	0.000	0.800	1.600	2.400	3.200
Total	100.000	100.000	100.000	100.000	100.000
Crude protein (%)	25.000	25.000	25.000	25.000	25.000
Metabolizable energy (Mcal/kg)	2.900	2.900	2.900	2.900	2.900
Methionine + cystine dig (%)	1.040	1.040	1.040	1.040	1.040
Lysine dig (%)	1.370	1.370	1.370	1.370	1.370
Threonine dig (%)	1.040	1.040	1.040	1.040	1.040
Tryptophan dig (%)	0.290	0.281	0.271	0.262	0.253
Valine dig (%)	1.061	1.032	1.002	0.973	0.944
Isoleucine dig (%)	0.995	0.965	0.936	0.907	1.718
Leucine dig (%)	1.896	1.851	1.807	1.370	1.869
Arginine dig (%)	1.615	1.566	1.517	1.468	1.419
Calcium (%)	0.850	0.850	0.850	0.850	0.850
Disposable phosphorus (%)	0.320	0.320	0.320	0.320	0.320
Sodium (%)	0.170	0.170	0.170	0.170	0.170

[a]Commercial product composed of 60% PB and 3.310 kcal/kg, with a safety level of 10% glutamine and 10% glutamic acid.
[b]Contents/kg: vit. A – 15.000.000 IU; vit. D3 – 1.500.000 IU; vit. E – 15.000 IU; vit. B1 - 2.0 g; vit. B2 - 4.0 g; vit. B6 - 3.0 g; vit. B12 - 0.015 g; nicotinic acid - 25 g; pantothenic acid - 10 g; vit. K3 - 3.0 g; folic acid - 1.0 g.
[c]Content/kg: Mn - 60 g; Fe - 80 g; Zn - 50 g; Cu - 10 g; Se - 250 mg; Co - 2 g; I - 1 g.

feed conversion of the birds was not influenced (P > 0.05) by the tested levels. In the regression analysis, except for the zero level of Gln+Glu in the analysis of variance, the performance of the birds was not affected (P > 0.05) by the levels of Gln+Glu in the diet.

From 22 to 42 days of age, the treatments showed no significant effect on the performance variables (P > 0.05); however, by the regression analysis, excluding the control treatment from the analysis of variance, only feed consumption was affected, presenting na increasing linear effect (P < 0.05), with an average of 527.82 g. In the total rearing period from 1 to 42 days of age, the performance variables were not influenced by the treatments (P > 0.05) either by Dunnett's test or by regression analysis.

The effect of glutamine supplementation levels associated with glutamic acid on the intestinal morphometry of broiler quails at 21 days of age is presented in table 3. For morphometry of the duodenum, by Dunnett's test, the only significant effect (P < 0.05) of the Gln+Glu supplementation levels was on the crypt depth, which was higher in the 0.6% Gln+Glu treatment, compared to the control

Table 2 - Feed intake (FI, g), weight gain (WG, g), and feed conversion (FC, g/g) of broiler quails subjected to glutamine supplementation levels associated with glutamic acid.

Phase	Supplementation (%)	FI (g)	WG (g)	FC (g/g)
	0.0	230.36±2.13	133.98±0.48	1.72±0.02
	0.2	225.91±3.19	132.05±1.01	1.71±0.03
01 to 21 days	0.4	221.08±2.99	131.16±1.21	1.69±0.02
	0.6	220.83±1.92*	132.37±0.83	1.67±0.02
	0.8	218.48±2.45*	129.58±0.61*	1.69±0.02
CV (%)		3.27	1.87	3.51
p-linear		0.06	0.12	0.33
p-quadratic		0.63	0.28	0.33
	0.0	537.52±4.59	138.87±4.12	3.89±0.10
	0.2	520.07±6.00	134.55±4.18	3.89±0.12
22 to 42 days	0.4	523.52±10.35	134.24±3.10	3.91±0.09
	0.6	528.30±4.71	138.91±1.64	3.81±0.08
	0.8	539.37±4.03	140.47±2.06	3.85±0.06
CV (%)		3.40	6.57	6.36
p-linear		0.03†	0.13	0.59
p-quadratic		0.55	0.77	0.91
	0.0	767.88±4.53	277.89±4.24	2.77±0.03
	0.2	745.98±7.15	272.20±5.72	2.75±0.05
01 to 42 days	0.4	744.60±11.95	260.93±6.74	2.86±0.07
	0.6	749.12±5.97	269.64±3.54	2.78±0.03
	0.8	757.85±3.38	270.71±3.44	2.80±0.03
CV (%)		2.72	5.14	4.43
p-linear		0.22	0.85	0.69
p-quadratic		0.49	0.22	0.29

*Mean differed from control treatment (0% Gln+Glu supplementation) by Dunnett test ($P < 0.05$).
†$Y = 227.21 - 11.27x$ ($R^2 = 87.08$).

treatment; however, the regression analysis excluding the treatment without glutamine and glutamic acid supplementation from the analysis of variance, showed no effect ($P > 0.05$) of Gln+Glu levels on the morphometry of this intestinal segment.

Birds' jejunum morphometry was affected ($P < 0.05$) by Gln+Glu supplementation levels for villus height and crypt depth. Villus height was lower at 0.4, 0.6, and 0.8% Gln+Glu levels; and crypt depth showed a significant reduction for all Gln+Glu supplementation treatments when compared to the control treatment. The analysis of variance by regression test, excluding the control treatment, showed a quadratic effect ($P < 0.05$) for villus height and crypt depth of the jejunum, estimating, respectively, minimum points at 0.59 and 0.58% of Gln+Glu supplementation, with respective measurements of 647.99 and 0.55 µm.

The morphometry of the ileum showed a significant effect ($P < 0.05$) only for villus height, both by Dunnett's test and regression analysis. Dunnett's test showed that the levels of 0.2, 0.6, and 0.8% of Gln+Glu were higher than the control treatment, while the regression analysis, excluding the control treatment, showed a quadratic effect, with lower villus height at the 0.51% Gln+Glu supplementation level, estimating a height of 614 µm.

Dietary supplementation of glutamine and glutamic acid did not influence ($P > 0.05$) the carcass characteristics, cuts, and edible viscera of broiler quails at 42 days of age (Table 4).

DISCUSSION

The performance results of the present study indicate that Gln+Glu supplementation in quails from 0.6% in the first three weeks of life triggers satiety mechanisms, reflected in the lower weight gain at the 0.8% dietary supplementation level. This response in performance can be explained by the aminostatic theory, in which the increase in the availability of glutamine and glutamic acid in the

Table 3 - Effect of dietary glutamine supplementation associated with glutamic acid on intestinal morphometry of broiler quails at 21 days of age.

Segment	Supplementation (%)	Villus height (µm)	Crypt depth (µm)	Villus:crypt ratio (µm)
	0.0	1585.40±0.10	74.90±1.27	21.36±0.36
	0.2	1582.18±38.71	77.20±1.34	20.62±0.53
Duodenum	0.4	1531.50±22.31	75.35±1.65	20.88±0.70
	0.6	1595.68±26.69	79.87±1.66*	20.30±0.52
	0.8	1516.03±25.68	73.20±1.15	20.22±0.40
CV (%)		11.67	10.52	15.60
p-linear		0.77	0.87	0.63
p-quadratic		0.39	0.24	0.51
	0.0	881.43±14.32	75.18±2.21	12.11±0.41
	0.2	849.73±17.41	70.28±2.02*	12.37±0.35
Jejunum	0.4	668.53±10.69*	56.50±1.36*	12.06±0.32
	0.6	673.08±10.46*	57.55±1.30*	11.88±0.27
	0.8	696.98±15.72*	59.55±1.12*	11.85±0.33
CV (%)		11.61	16.52	17.54
p-linear		<0.01	<0.01	0.14
p-quadratic		<0.01†	<0.01‡	0.58
	0.0	588.65±18.46	54.85±1.42	10.96±0.40
	0.2	650.90±11.56*	58.63±1.74	11.44±0.36
Ileum	0.4	606.58±11.90	57.40±2.17	11.11±0.42
	0.6	628.68±12.21*	58.43±1.87	11.11±0.35
	0.8	640.90±13.80*	59.33±1.97	11.28±0.43
CV (%)		13.51	20.40	22.30
p-linear		0.54	0.87	0.88
p-quadratic		<0.01§	0.46	0.40

*Mean differed from control (0% Gln+Glu supplementation) by Dunnett test ($P < 0.05$).
†$Y = 1091.9 - 1508.7x + 1281.9x^2$ ($R^2 = 93.76$).
‡$Y = 88.48 - 114.2x + 98.625x^2$ ($R^2 = 92.0$).
§$Y = 704.41 - 357.33x + 353.38x^2$ ($R^2 = 73.38$).

organism causes aminoacid imbalance in relation to the real needs of the animals, resulting in a reduction of the feed consumption by the excitation of hypothalamic control areas (GLEAVES, 1989; GONZALES, 2002). Even so, the fact that the diet was not isoaminoacidic may have contributed to the results.

On the other hand, SALMANZADEH et al. (2013) reported a significant increase in weight gain in Japanese quails supplemented with 30 and 40 mg/kg of glutamine. Similarly, SALLAM et al. (2019) reported improved weight gain and feed conversion in 42-d-old Japanese quails that had been supplemented in ovo with glutamine. Nevertheless, studies with poultry from other species have demonstrated well-marked limits of glutamine supplementation. For example, SOLTAN et al. (2009), obtained higher feed intake and weight gain of birds supplemented with 1% glutamine; however, when increasing the level to 1.5 and 2.0%, the authors found that feed intake and weight gain worsened. They concluded that high levels of glutamine can result in lower feed intake, lower weight gain, and even cause toxicity in animals. Similarly, BARTELL et al. (2007) reported an improvement in the weight gain of broiler chicks supplemented with 1% glutamine in the diet during the first three weeks of life, but the weight of the birds decreased when the level of supplementation was increased to 4%.

Thus, the performance results seen in the present study showed possible particularities of broilers quails in response to glutamine and glutamic acid supplementation, differing from what had been described in most studies focusing on other poultry (FASINA et al., 2010; DAI et al., 2011; SAKAMOTO et al., 2011; NASCIMENTO et al., 2014; FIGUEIREDO et al., 2015). Authors such as SAKAMOTO et al. (2006) and FIGUEIREDO et al. (2015) found no significant difference in the

Table 4 - Absolute (g) and relative (%) weights of carcass, cuts and edible viscera of European quails at 42 days of age subjected to supplementation levels of glutamine associated with glutamic acid in the diet.

Absolute Weight (g)	-----------------------------------Supplementation level (%)--------------------------------					CV (%)	p-linear	p-quadratic
	0.0	0.2	0.4	0.6	0.8			
Slaughter weight	285.00±6.53	274.69±8.53	270.94±7.13	276.56±4.55	270.31±4.48	6.76	0.80	0.85
Carcass	203.74±5.39	199.88±4.48	197.66±2.71	197.60±2.32	200.41±3.01	5.33	0.93	0.51
Breast Meat	85.70±2.30	84.27±2.59	86.12±1.66	85.21±1.10	85.18±2.16	6.73	0.84	0.65
Back	62.55±2.81	60.13±1.71	58.73±1.29	56.75±0.57	61.03±1.53	8.24	0.93	0.11
Legs	40.48±1.27	40.17±1.02	39.94±0.98	41.27±1.78	41.14±0.53	8.29	0.43	0.97
Wings	12.95±0.42	11.67±0.25	12.50±0.28	13.42±0.42	12.05±0.12	8.02	0.96	0.95
Heart	2.15±0.08	2.25±0.05	2.07±0.04	2.27±0.08	2.13±0.08	9.19	0.63	0.83
Liver	5.13±0.36	4.77±0.53	4.58±0.47	5.52±0.34	4.68±0.42	27.93	0.15	0.51
Gizzard	4.38±0.15	4.37±0.18	4.17±0.14	4.66±0.13	4.46±0.15	9.57	0.26	0.99
--Relative weight (%)---								
Carcass	71.55±1,42	72.95±1.17	73.16±1.30	71.52±0.96	74.26±1.20	4.74	0.68	0.31
Breast Meat	42.12±0.84	42.13±0.70	43.56±0.40	43.14±0.50	42.46±0.53	4.18	0.83	0.10
Back	30.64±0.80	30.08±0.47	29.72±0.59	28.73±0.24	30.47±0.73	5.67	0.95	0.09
Legs	19.86±0.22	20.10±0.33	20.21±0.43	20.85±0.73	20.55±0.29	6.08	0.32	0.64
Wings	6.38±0.25	5.85±0.12	6.32±0.13	6.79±0.21	6.02±0.10	7.17	0.69	0.46
Heart	1.06±0.04	1.13±0.03	1.05±0.02	1.15±0.04	1.06±0.04	8.95	0.55	0.89
Liver	2.53±0.19	2.37±0.24	2.31±0.22	2.79±0.17	2.33±0.19	6.54	0.71	0.39
Gizzard	2.15±0.08	2.18±0.06	2.11±0.6	2.35±0.06	2.22±0,04	8.01	0.20	0.64

performance of chickens that received glutamine supplementation at 1% and 0.5 to 1.5%, respectively, in the feed. Also, no improvement in the productive performance of broilers subjected to different densities and fed with 0.5% glutamine and glutamic acid in the diet was reported (SHAKERI et al., 2014).

The morphometric results of the intestine justify the performance of the birds in their first three weeks of life; the jejunum, the main site of absorption of most of the nutrients, showed a reduction in villus height by supplementation at levels greater than 0.2%, and this probably impaired the utilization of nutrients. On the other hand, the greater development of the ileum in response to supplementation levels can be explained by the lower amount of Gln+Glu that reached this segment when compared to the jejunum; while the levels above 0.2% were high for the development of the jejunum, the rest of the supplemented amino acids that reached the ileum were quantitatively sufficient to favor the development of the mucosa of this segment.

The relationship between glutamine and increased intestinal villus length in poultry has been described by other authors (BARTELL et al., 2007; SOLTAN et al., 2009; SALMANZADEH et al., 2016). In Japanese quails, glutamine supplementation resulted in expressive increase in villus height in the jejunum of birds at 21 and 42 days of age (SALMANZADEH et al., 2013). However, increased villus size and less intestinal mucosal wasting are not always associated with better growth responses in birds (SAKAMOTO et al., 2006; PELÍCIA et al., 2013; FIGUEIREDO et al., 2015). Although the early development of the intestinal mucosa is important for the performance of the animal, the greater the height and density of villi, the higher the energy cost of maintenance (REISINGER et al., 2011). SALLAM et al. (2019) reported no differences in the relative intestine weight of Japanese quails at 42 days of age that had been supplemented in ovo with glutamine when compared with the non-supplemented control group.

The data obtained for the carcass and internal organs are consistent with performance, because the weight gain and feed conversion of birds did not vary between treatments from 1 to 42 days of age. Corroborating this proposition, NASCIMENTO et al. (2014) and FIGUEIREDO et al. (2015), found no variation in the carcass characteristics of broilers supplemented with glutamine.

CONCLUSION

Glutamine and glutamic acid supplementation affected the performance and intestinal morphology of 21-d-old quails, decreasing feed intake and weight gain associated with the improvement of ileum morphology; on the other hand, performance and carcass characteristics at 42 days were not affected by amino acid supplementation.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the conception and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

All procedures in this study were approved by the Ethics Committee on Animal Use of the Universidade Federal da Paraíba (Protocol No. 118/2015).

REFERENCES

BARTELL, S. M.; BATAL, A. B. The effect of supplemental glutamine on growth performance, development of the gastrointestinal tract, and humoral immune response of broilers. **Poultry Science**, v.86, p.1940-1947, 2007. Available from: <https://doi.org/10.1093/ps/86.9.1940>. Accessed: Jun. 20, 2021. doi: 10.1093/ps/86.9.1940.

BEZERRA, R. M. et al. Glutamic acid supplementation on low protein diets for laying hens. **Acta Science Animal Science**, v.37, p.129-134, 2015. Available from: <https://doi.org/10.4025/actascianimsci.v37i2.25911>. Accessed: Jun. 21, 2021. doi: 10.4025/actascianimsci.v37i2.25911.

CASTRO, M. R. et al. Digestible threonine to lysine ratios for meat-type Brazilian quails. **Brazilian Journal of Poultry Science**, v.22, n.1, p.1-8, 2020. Available from: <http://dx.doi.org/10.1590/1806-9061-2017-0636>. Accessed: Jun. 20, 2021. doi: 10.1590/1806-9061-2017-0636.

CRUZ, F. K. et al. Development and growth of digestive system organs of European and Japanese quail at 14 days post-hatch. **Poultry Science**, v.98, n.4, p.1883-1892, 2019. Available from: <https://doi.org/10.3382/ps/pey492>. Accessed: Jun. 20, 2021. doi: 10.3382/ps/pey492.

DAI, S. F. et al. Effects of dietary glutamine and gamma-aminobutyric acid on performance, carcass characteristics and serum parameters in broilers under circular heat stress. **Animal Feed Science Technology**, v.168, p.51-60, 2011. Available from: <https://doi.org/10.1016/j.anifeedsci.2011.03.005>. Accessed: Jun. 20, 2021. doi: 10.1016/j.anifeedsci.2011.03.005.

FASINA, Y. O. et al. Effect of dietary glutamine supplementation on *Salmonella* colonization in the ceca of young broiler chicks. **Poultry Science**, v.89, p.1042-1048, 2010. Available from: <https://doi.org/10.3382/ps.2009-00415>. Accessed: Jun. 22, 2021. doi: 10.3382/ps.2009-00415.

FIGUEIREDO, É. M. et al. Glutamine for broilers kept in thermoneutrality from 21 to 42 days. **Semina: Agricultural Sciences**, v.36, p.1633-1642, 2015. Available from: <https://doi.org/10.5433/1679-0359.2015v36n3p1633>. Accessed: Jun. 20, 2021. doi: 10.5433/1679-0359.2015v36n3p1633.

GLEAVES, E. W. Application of feed intake principles to poultry care and management. **Poultry Science**, v.68, p.958-969, 1989. Available from: <https://doi.org/10.3382/ps.0680958> Accessed: Jun. 20, 2021. doi: 10.3382/ps.0680958.

GONZALES, E. Food intake: regulatory mechanisms. In: Macari M, Furlan RL, Gonzales E, editors. **Fisiologia aviária aplicada a frangos de corte**. Jaboticabal: Funep-Unesp; p.187-200. 2002.

NASCIMENTO, G. M. et al. Performance and intestinal characteristics of broiler chicken fed diet with glutamine in the diet without anticoccidials agents. **Revista Brasileira de Saúde e Produção Animal**, v.15, p.637-648, 2014. Available from: <https://doi.org/10.1590/S1519-99402014000300011>. Accessed: May, 20, 2021. doi: 10.1590/S1519-99402014000300011.

PELÍCIA, V. C. et al. Phytogenic additives and glutamine plus glutamic acid in broiler diets. **Revista Brasileira de Ciência Avícola**, v.15, p.295-300, 2013. Available from: <https://doi.org/10.1590/S1516-635X2013000400002>. Accessed: Jun. 20, 2021. doi: 10.1590/S1516-635X2013000400002.

REISINGER, N. et al. Effects of a blend of essential oils on broiler performance and intestinal morphology during coccidial vaccine exposure. **Journal of Applied Poultry Research**, v.20, p.272-283, 2011. Available from: <https://doi.org/10.3382/japr.2010-00226>. Accessed: Jun. 23, 2021. doi: 10.3382/japr.2010-00226.

REZAEI, M. A. et al. Body growth, intestinal morphology and microflora of quail on diets supplemented with micronised wheat fibre. **British Poultry Science**, v.59, n.4, p.422-429, 2018. Available from: <https://doi.org/10.1080/00071668.2018.1460461>. Accessed: Jun. 20, 2021. doi: 10.1080/00071668.2018.1460461.

SAKAMOTO, M. I. et al. Influence of glutamine and vitamin E on the performance and the immune responses of broiler chickens. **Revista Brasileira de Ciencia Avicola**, v.8, p.243-249, 2006. Available from: <https://doi.org/10.1590/S1516-635X2006000400007>. Accessed: Jun. 23, 2021. doi: 10.1590/S1516-635X2006000400007.

SAKAMOTO, M. I. et al. Utilization of glutamine, associated with glutamic acid, on the development and enzymatic activity in broilers. **Arquivo Brasileiro de Medicina Veterinária e**

Zootecnia, v.63, n.4, p.962-972, 2011. Available from: <https://doi.org/10.1590/S0102-09352011000400023>. Accessed: Jun. 23, 2021. doi: 10.1590/S0102-09352011000400023.

SALLAM, M. G. et al. Effect of in ovo nano-selenium and glutamine on hatchability, post-hatch performance and some blood biochemical indices in japanese quail. **Arab Universities Journal of Agricultural Sciences**, v.27, n.4, p.2321-2328, 2019. Available from: <https://doi.org/10.21608/ajs.2019.16897.1086>. Accessed: Dec. 16, 2022. doi: 10.21608/ajs.2019.16897.1086.

SALMANZADEH, M. et al. The effects of in ovo feeding of glutamine in broiler breeder eggs on hatchability, development of the gastrointestinal tract, growth performance and carcass characteristics of broiler chickens. **Archives Animal Breeding**, v.59, n.2, p.235-242, 2016. Available from: <https://doi.org/10.5194/aab-59-235-2016>. Accessed: Jun. 23, 2021. doi: 10.5194/aab-59-235-201610.5194/aab-59-235-2016.

SALMANZADEH, M. et al. Effects of dietary glutamine addition on growth performance, carcass characteristics and development of the gastrointestinal tract in Japanese quails. **Revue de Médecine Vétérinaire**, v.164, n.10, p.471-475, 2013. Available from: <https://www.cabdirect.org/cabdirect/abstract/20133353437>. Accessed: Dec. 16, 2021.

SHAKERI, M. et al. Response to dietary supplementation of L-glutamine and L-glutamate in broiler chickens reared at different stocking densities under hot, humid tropical conditions. **Poultry Science**, v.93, n.11, p.2700-2708, 2014. Available from: <https://doi.org/10.3382/ps.2014-03910>. Accessed: Jun. 20, 2021. doi: 10.3382/ps.2014-03910.

SILVA, J. H. V.; COSTA, F. G. P. **Tabela para codornas japonesas e europeias**. Jaboticabal: Funep-Unesp; 2009.

SOLTAN, M. A. Influence of dietary glutamine supplementation on growth performance, small intestinal morphology, immune response and some blood parameters of broiler chickens. **International Journal of Poultry Science**, v.8, n.1, p.60-68, 2009. Available from: <https://doi.org/10.3923/ijps.2009.60.68>. Accessed: Jun. 20, 2021. doi: 10.3923/ijps.2009.60.68.