Chapter

Evaluation of Protein Sources in Different Base Formulations Based on Total and Digestible Amino Acids for Japanese Quails

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Abstract

The Japanese quail (*Coturnix coturnix japonica*) rearing activity has grown considerably over the past few years. The purpose of this study was to compare diet formulations based on total (TAA) and digestible amino acids (DAA) and the use of different protein sources such as meat cum bone meal and feather meal in Japanese quails. The first three treatments were based on TAA, formulated based on corn and soybean meal (CST); meat and bone meal (CSMT); feather meal (CSMFT). The three other treatments received the same sequence of ingredients as the previous treatments; however, the diets were formulated based on digestible amino acids (DAA) (CSD, CSMD, and CSMFD). The results show that the base of diet formulation improves the performance of quails from 1-21d and the quails show that is possible to replacement of soybean meal with animal-origin by-products such as meat bone meal and feather meal, buts is needed to evaluate more aspects. In conclusion, diets formulated base on DAA for Japanese quails can be utilized with the same efficiency as diets based on TAA.

Keywords: amino acid, feed formulation, performance, protein sources

1. Introduction

The Japanese quail (*Coturnix coturnix japonica*) rearing activity has grown considerably over the past few years. Diversification of production in small and medium-sized properties, quick working capital, and reduction in production costs, compared with commercial layers, has intensified this growth.

The starter and growth phases of Japanese quails, from hatching to 42 days, is the critical time to manipulate these birds; within a short period, the quails become adults and are physiologically capable of laying eggs. Thus, any alteration in the nutrient levels or diet ingredients during this early phase significantly impacts the growth and development of the reproductive tract of birds. Diet formulation based on digestible amino acids (DAA) is a modern concept in poultry nutrition. This represents an advancement concerning diet formulation based on total amino acids (TAA) due to the greater reliability of the results in the assays of substitution of conventional feeds with feeds having more efficient protein deposition and of lower cost [1].

Nutritionists are now utilizing these formulations. This development is especially important due to the demand for optimizing the use of expensive raw materials and replacing corn and soybean meal with alternative ingredients, ensuring an equivalent uptake of DAA through the correction of deficiencies with supplementation of crystalline amino acids [2]. Formulation based on DAA, including meat and bone and feather meal, facilitates the absorption of greater amounts of lower quality protein sources and at lower costs, compared with soybean meal. Production costs are consequently lower, demonstrating the economic advantage of using this process. The cheapest diet formulation programs select feedstuffs that will produce the diet according to their price and nutritional value. From this perspective, the utilization of the formulation system based on DAA may be more effective than the formulation based on TAA as the nutritional value of the feedstuffs is better evaluated [3]. Thus, this study aimed to evaluate the effectiveness of diet formulations for Japanese quails based on DAA, compared with those based on TAA, using different protein sources.

2. Methodology of this research

The study was conducted in the Module of Poultry Science, in Areia-PB, Brazil. Located at latitude: −6.96179, longitude: −35.6953, 6 ° 57 ′ 42 ″ South, 35 ° 41′ 43 ″ West. All experimental protocols and procedures were approved by the Ethics Committee in Animal Experimentation (CEUA, n. 3363/18).

The first three treatments were subjected to diets formulated based on total amino acid (TAA), in which the first was formulated based on corn and soybean meal (CST); the second, in addition to corn and soybean meal, received meat and bone meal (CSMT); the third, in addition to the previously listed ingredients, received feather meal (CSMFT). The three other treatments received the same sequence of ingredients as the previous treatments; however, the diets were formulated based on digestible amino acids (DAA) (CSD, CSMD, and CSMFD). A completely randomized design was used with treatments.

A total of 576 female Japanese quails from one-day to 21 days (Starter phase, 1-21d) were distributed in six treatments with eight replications of 12 birds in each. A total of 480 female Japanese quails from 22 to 42 days (Growth phase, 22-42d) were distributed in six treatments with eight replications of 10 birds in each. A total of 288 female Japanese quails in the egg-laying phase were distributed in six treatments with six replications of eight birds in each, which period was divided into four cycles of 21 days, totaling 84 days.

For the formulation of diets, the nutritional requirements recommended by [4] and the total and digestible amino acid values of the ingredients recommended by [5] were considered. To calculate the DAA values, the TAA values were multiplied by the digestibility coefficients of the amino acids in the ingredients found by [5]. Daily management during the experimental period was based on feeding birds, washing drinkers, changing the water, cleaning the site, recording mortality, and collecting the orts to correct the calculations of the variables. The nutritional composition of experimental diets for Japanese quails from 1 to 21 and 22 to 42 days are presented respectively in (**Tables 1** and **2**). The nutritional composition of experimental diets for laying Japanese quails is in (**Table 3**).

Ingredients	Total amino acids			Digestible amino acids		
	CST	CSMT	CSMFT	CSD	CSMD	CSMFD
Corn	526.22	564.91	567.34	544.46	573.48	564.02
Soybean meal	441.89	393.74	377.00	426.67	383.80	385.09
Meat and Bone meal	—	26.47	25.35	—	26.65	25.54
Feather meal	—	—	15.85	—	—	11.97
Bicalcium phosphate	9.40	0.000	0.000	9.48	0.000	0.000
Limestone	5.46	4.95	5.24	5.52	4.98	5.16
Soybean oil	9.61	0.000	0.000	6.49	0.000	0.96
Salt	2.36	2.08	1.97	2.38	5.04	1.99
DL-Methionine	1.46	1.93	1.50	1.48	1.64	1.42
L-Threonine	0.60	1.34	1.02	0.52	0.77	0.44
L-Lysine.HCl	0.00	1.58	1.73	0.00	0.64	0.41
Choline Chloride	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin mix[1]	1.00	1.00	1.00	1.00	1.00	1.00
Mineral mix[2]	1.00	1.00	1.00	1.00	1.00	1.00
Total	1,000	1,000	1,000	1,000	1,000	1,000
Nutritional Composition (g/kg)						
ME (kcal/kg)	2,900	2,900	2,900	2,900	2,900	2,900
CP, g/kg	250.3	249.4	249.5	249.2	249.2	249.7
Calcium, g/kg	6.0	6,0	6.0	6.0	6.0	6.0
Available phosphorus, g/kg	3.0	3.0	3.0	3.0	3.0	3.0
Sodium, g/kg	1.40	1.40	1.40	1.40	1.40	1.40
Lysine, g/kg	13.6	13.6	13.6	—	—	—
Dig. Lysine, g/kg	—	—	—	11.9	11.9	11.9
Methionine+cystine, g/kg	9.0	9.0	9.0	—	—	—
Dig. Methionine+cystine, g/kg	—	—	—	8.0	8.0	8.0
Threonine, g/kg	10.2	10.2	10.2	—	—	—
Dig. Threonine, g/kg	—	—	—	8.70	8.70	8.70
Tryptophan, g/kg	3.20	2.90	2.80	—	—	—
Dig. Tryptophan, g/kg	—	—	—	2.80	2.60	2.70
Arginine, g/kg	1.68	1.54	1.57	—	—	—
Dig. Arginine, g/kg	—	—	—	16.6	16.0	16.6
Valine, g/kg	11.50	10.60	11.20	—	—	—
Dig. valine, g/kg	—	—	—	10.0	9.80	10.30

[1]*Vitamin mix composition basic of product: monoxide manganese, zinc oxide, iron sulfate, copper sulfate, calcium iodide, vehicle QSP Assurance levels per kg of product: 150.000 mg Manganese, Zinc 100,000 mg, Iron 100,000 mg, 16,000 mg Copper, Iodine 1,500 mg*
[2]*Mineral mix composition basic of product: Vit. A, Vit. D3, Vit. And, Vit. K, Vit. B1, vit. B2, Vit. B6, Vit. B12, Niacin, Folic Acid, Pantothenic Acid, Sodium Selenite, Antioxidant, Vehicle QSP Assurance levels per kg of product: Vit. The 10,000.00 U.I, Vit. 2,500,000 U.I D3, Vit. And U.I 6,000, Vit. K 1,600 mg Vit. B12 11,000, 25,000 mg Niacin, Folic Acid 400 mg Pantothenic Acid 10,000 mg, 300 mg Selenium, Antioxidant 20 g.*

Table 1.
Nutritional composition of experimental diets for Japanese quails from 1 to 21 days.

Ingredients	TAA			DAA		
	CST	CSMT	CST	CSMT	CST	CSMT
Corn	629.48	647.49	661.72	627.8	643.64	664.88
Soybean meal	334.72	307.85	286.12	336.92	312.87	284.79
Meat and Bone meal	—	20.55	20.00	—	20.45	20.00
Feather meal	—	—	10.00	—	—	10.00
Bicalcium phosphate	7.35	0.00	0.00	7.34	0.00	0.00
Limestone	4.99	4.56	4.78	4.98	4.54	4.79
Soybean oil	13.23	7.97	5.63	13.75	9.18	5.46
Salt	2.48	2.25	2.18	2.47	2.24	2.18
DL-Methionine	1.74	2.01	1.84	1.62	1.66	1.71
L-Threonine	1.58	2.00	1.96	1.21	1.28	1.39
L-Lysine.HCl	1.43	2.33	2.77	0.91	1.13	1.80
Choline Chloride	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin mix[1]	1.00	1.00	1.00	1.00	1.00	1.00
Mineral mix[2]	1.00	1.00	1.00	1.00	1.00	1.00
Total	1,000	1,000	1,000	1,000	1,000	1,000
Nutritiona Composition (g/kg)						
ME (kcal/kg)	3,050	3,050	3,050	3,050	3,050	3,050
CP, g/kg	220.0	220.0	220.0	220.0	220.0	219.0
Calcium, g/kg	5.00	5.00	5.00	5.00	5.00	5.00
Available phosphorus,g/kg	2.50	2.50	2.50	2.50	2.50	2.50
Sodium, g/kg	1.40	1.40	1.40	1.40	1.40	1.40
Lysine, g/kg	12.0	12.0	12.0	—	—	—
Lisina dig, g/kg	—	—	—	10.5	10.5	10.5
Methionine+cystine, g/kg	8.30	8.30	8.30	—	—	—
Methionine+cystine dig, g/kg	—	—	—	7.40	7.40	7.40
Threonine, g/kg	9.60	9.60	9.60	—	—	—
Threonine dig, g/kg	—	—	—	8.20	8.20	8.20
Triptophan, g/kg	0.26	0.24	0.23	—	—	—
Tryptophan dig, g/kg	—	—	—	0.23	0.22	0.21
Arginine, g/kg	1.37	1.28	1.27	—	—	—
Arginine dig, g/kg	—	—	—	1.38	1.37	1.32
Valine, g/kg	0.96	0.91	0.93	—	—	—
Valine dig, g/kg	—	—	—	0.86	0.86	0.86

[1]*Vitamin mix composition basic of product: monoxide manganese, zinc oxide, iron sulfate, copper sulfate, calcium iodide, vehicle QSP Assurance levels per kg of product: 150.000 mg Manganese, Zinc 100,000 mg, Iron 100,000 mg, 16,000 mg Copper, Iodine 1,500 mg.*
[2]*Mineral mix composition basic of product: Vit. A, Vit. D3, Vit. And, Vit. K, Vit. B1, vit. B2, Vit. B6, Vit. B12, Niacin, Folic Acid, Pantothenic Acid, Sodium Selenite, Antioxidant, Vehicle QSP Assurance levels per kg of product: Vit. The 10,000.00 U.I, Vit. 2,500,000 U.I D3, Vit. And U.I 6,000, Vit. K 1,600 mg Vit. B12 11,000, 25,000 mg Niacin, Folic Acid 400 mg Pantothenic Acid 10,000 mg, 300 mg Selenium, Antioxidant 20 g.*

Table 2.
Nutritional composition of experimental diets for Japanese quails from 22 to 42 days.

Ingredients	TAA			DAA		
	CST	CSMT	CST	CSMT	CST	CSMT
Corn	553.47	569.45	601.31	563.58	575.89	619.98
Soybean meal	338.72	313.91	264.2	330.27	309.56	245.55
Meat and Bone meal	—	20.0	20.0	—	20.0	35.53
Feather meal	—	—	22.8	—	—	18.16
Bicalcium phosphate	13.05	5.88	5.43	13.09	5.9	—
Limestone	65.14	64.71	65.19	65.18	64.73	64.8
Soybean oil	20.32	15.48	10.15	18.58	14.7	5.6
Salt	4.79	4.57	4.41	4.8	4.57	4.27
DL-Methionine	1.47	1.72	1.33	1.5	1.52	1.6
L-Threonine	0.04	0.44	0.34	—	—	0.17
L-Lysine.HCl	—	0.83	1.85	—	0.13	1.34
Choline Chloride	1.00	1.00	1.00	1.00	1.00	1.00
Vitamin mix[1]	1.00	1.00	1.00	1.00	1.00	1.00
Mineral mix[2]	1.00	1.00	1.00	1.00	1.00	1.00
Total	1,000	1,000	1,000	1,000	1,000	1,000
Nutritional Composition (g/kg)						
ME (kcal/kg)	2,850	2,850	2,850	2,850	2,850	2,850
CP, g/kg	203	203	203	200	200	199
Calcium, g/kg	2.95	2.95	2.95	2.95	2.95	2.95
Available phosphorus, g/kg	3.5	3.5	3.5	3.5	3.5	3.5
Sodium, g/kg	2.3	2.3	2.3	2.3	2.3	2.3
Lysine, g/kg	10.8	10.8	10.8	—	—	—
Lysine dig, g/kg	—	—	—	9.5	9.5	9.5
Methionine+cystine, g/kg	7.8	7.8	7.8	—	—	—
Methionine+cystine dig, g/kg	—	—	—	7.0	7.0	7.0
Threonine, g/kg	7.9	7.9	7.9	—	—	—
Threonine dig, g/kg	—	—	—	0.67	6.7	6.7
Tryptophan, g/kg	2.5	2.4	2.2	—	—	—
Tryptophan dig, g/kg	—	—	—	2.2	2.2	1.9
Arginine, g/kg	13.5	12.7	12.4	—	—	—
Arginine dig, g/kg	—	—	—	13.3	13.3	12.6
Valine, g/kg	9.4	9.0	9.4	—	—	—
Valine dig, g/kg	—	—	—	8.3	8.2	8.3

[1]*Vitamin mix composition basic of product: monoxide manganese, zinc oxide, iron sulfate, copper sulfate, calcium iodide, vehicle QSP Assurance levels per kg of product: 150.000 mg Manganese, Zinc 100,000 mg, Iron 100,000 mg, 16,000 mg Copper, Iodine 1,500 mg.*
[2]*Mineral mix composition basic of product: Vit. A, Vit. D3, Vit. And, Vit. K, Vit. B1, vit. B2, Vit. B6, Vit. B12, Niacin, Folic Acid, Pantothenic Acid, Sodium Selenite, Antioxidant, Vehicle QSP Assurance levels per kg of product: Vit. The 10,000.00 U.I, Vit. 2,500,000 U.I D3, Vit. And U.I 6,000, Vit. K 1,600 mg Vit. B12 11,000, 25,000 mg Niacin, Folic Acid 400 mg Pantothenic Acid 10,000 mg, 300 mg Selenium, Antioxidant 20 g.*

Table 3.
Nutritional composition of experimental diets for laying Japanese quails.

In the phases of 1 to 21 and 22 to 42 days of age, the quails were housed in masonry pens with wood partitions. Each pen had a drinker and feeder for quails at the starter phase and heating was provided by incandescent light bulbs. Feed intake (FI) was calculated as the difference between the amount of feed supplied and collected orts, weighed at the beginning and end of each experimental phase. For the determination of weight gain (WG), birds were also weighed at the beginning and end of the experimental period. Feed conversion (FC) was calculated by dividing the accumulated FI by WG in the experimental period, adjusting the data by weighing feed and dead birds whenever there was mortality.

The economic evaluation of activity was performed during the entire experimental period through the relative gross margin (RGM), that is the gross margin (GM) of the diets formulated based on DAA concerning the GM of the diets formulated based on TAA. Similarly, the RGM of the diets with the inclusion of meat and bone meal and feather meal concerning the diet formulated based on corn and soybean meal was calculated. The determination of RGM was completed considering only the variable costs of feeding once the fixed costs were equal for all treatments. For these calculations, we considered the FI and the number of eggs laid by quails during the experimental period. Based on the price of inputs, it was possible to calculate the costs of each experimental diet per kilogram. The cost of feeding was obtained by multiplying this value by FI (in kg/bird). Gross income was calculated by multiplying the number of dozens produced in the period by the price of one dozen quail eggs in practice for retail in the Northeast region of Brazil. The GM of each treatment was calculated by the difference between the gross income and the cost of feeding.

The data were subjected to variance analyses using the computer package SAEG (Sistema para Análises Estatísticas e Genéticas, 9.1) and means were compared using a Tukey's test at 5% probability according to the statistical model $Yij = \mu + Ti + eij$, in which Yij is the response variable obtained in subject j, receiving treatment i; Ti is the effect of the additional treatment; eij is the experimental error associated with the additional treatment. The contrasts between the means of the variables obtained with the diet formulation based on digestible and total amino acids were also tested.

3. Results and discussion of this research

The performance results obtained from phase 1 to 21 days (**Tables 4** and **5**) show that there was a significant difference ($P < 0.05$) between the base formulations and the ingredients utilized only for FI in the diet based on corn and soybean meal (CS). Formulation based on TAA or DAA did not significantly influence WG; however, FC was higher with DAA. Birds during the starter phase deposited less dietary protein compared with older birds.

No effect of the formulation bases and ingredients utilized on performance was observed ($P > 0.05$) during the growth phase (**Table 6**). Likewise, neither the formulation based on TAA nor DAA influenced the performance values assessed. Evaluation of diets containing CS, CSM, and CSMF indicated no significant differences between the variables analyzed. Base formulations and ingredients utilized did not affect the performance of the quails ($P > 0.05$; **Table 7**).

Base formulations and the ingredients influenced the shell percentage significantly ($P < 0.05$) (**Table 8**). However, no significant differences were observed for any of the egg quality variables studied (**Table 9**).

The average results of the digestibility assay are presented in (**Table 10**). The diets that contained CSMFT presented greater nitrogen excretion.

	Ingredient		
Formulation basis	CS[3]	CSMB[4]	CSMBF[5]
TAA[1]	168.2 Aa	155.7 B	164.8 AB
DAA[2]	151.4 b	156.5	157.1
CV		3,38	

[A,B a,b] Means followed by different capital letters in the same row and different small letters in the same column differ statistically by the Tukey test at 5% probability.
[1]Total Amino acids.
[2]Corn and Soybean Meal.
[3]Digestible Amino Acids.
[4]Corn, Soybean Meal, Meat and bone Meal.
[5]Corn, Soybean Meal, Meat and Bone Meal, Feather Meal.

Table 4.
Effect of base formulations of different ingredients on feed intake (g) in Japanese quails from 1 to 21 days.

	Body weight (g/bird)	Weight gain (g/bird)	Feed conversion (g/g)
TAA[1]	70.7	63.4	2.596 A
DAA[2]	70.6	63.3	2.450 B
CS[3]	69.4 B	62.1 B	2.572
CSMB[4]	70.6 AB	63.3 AB	2.467
CSMBF[5]	72.0 A	64.7 A	2.489
CV	2.41	2.79	4.58

a,b Means followed by different letters in the same column differ by Tukey testat5% probability.
[1]Total Amino Acids.
[2]Digestible Amino Acid.
[3]Corn and Soybean Meal.
[4]Corn, Soybean Meal and Meat and Bone Meal.
[5]Corn, Soybean Meal, Meat and Bone Meal and Feather Meal.

Table 5.
Effect of base of formulation of different ingredients on body weight, weight gain and feed conversion in Japanese quails from1 to 21 days.

Base of formulationq	Feed intake (g/Bird)	Body weight (g/bird)	Weight Gain (g/bird)	Feed conversion ratio (g/g)
TAA[1]	393.3	158.7	93.2	4.22
DAA[2]	385.1	157.1	91.9	4.19
Ingredients				
CS[3]	387.7	159.1	93.7	4.14
CSMMSC[4]	389.8	156.3	91.1	4.28
MSCP[5]	387.7	158.1	92.9	4.20
CV (%)	5.78	3.55	6.07	5.06

[1]TotalAmino Acids.
[2]Digestible. Amino Acid.
[3]Corn and Soybean Meal.
[4]Corn, Soybean Meal and Meat and Bone Meal.
[5]Corn, Soybean Meal, Meat and Bone Meal and Feather Meal.

Table 6.
Effect of base of formulation of different ingredients in feed intake, body weight, weight gain and feed conversion in Japanese quails from 22 to 42 days.

Variables	TAA[1]	DAA[2]	CS[3]	CSMB[4]	CMBF[5]
Feed intake (g/ day)	25.494a	25.633a	25.938a	26.069a	24.684b
Egg production (%)	88.59 a	87.19a	89.55a	86.11b	88.02ab
Egg weight (g)	11.554	11.679	11.585	11.741	11.525
Egg mass (g/bird/day)	10.236	10.178	10.373	10.107	10.142
Egg mass conversion (g/g)	2.493ab	2.522ab	2.502ab	2.581a	2.438b
Conversion per dozen eggs (kg/dz)	0.345ab	0.351ab	0.348ab	0.363a	0.334b

[1]*Total amino acids.*
[2]*Digestible amino acids.*
[3]*Corn and soybean meal.*
[4]*Corn, Soybean meal, meat and bone meal.*
[5]*Corn, Soybean meal, meat and bone meal and feather meal.*

Table 7.
Performance characteristics of laying Japanese quails fed diets based on total amino acids (TAA) and digestible amino acids (DAA) and with different ingredients in this composition.

Base Formulation	CS[3]	CSMB[4]	CSMBF[5]
TAA[1]	7.53b	7.78 ab	8.01ab
DAA[2]	7.90ab	7.99ab	8.13 a
CV (%)		3.59	

[A,B a,b] *Means followed by different capital letters in the same row and different small letters in the same column differ statistically by the Tukey test at 5% probability.*
[1]*Total amino acids.*
[2]*Digestible amino acids.*
[3]*Corn and soybean meal.*
[4]*Corn, Soybean meal, meat and bone meal.*
[5]*Corn, Soybean meal, meat and bone meal and feather meal.*

Table 8.
Effect of base formulation and different ingredients in shell percentage (%) of laying Japanese quails[1].

	TAA[1]	DAA[2]	CS[3]	CSMB[4]	CSMBF[5]	CV(%)
Albumen, %	54.17	54.15	54.20	54.41	53.88	2.78
Height Albumen, mm	4.31	4.34	4.260	4.335	4.383	5.81
Yolk, %	33.09	32.53	32.95	32.46	32.99	3.66
Specific gravity (g/cm^3)	1.070	1.070	1.070	1.070	1.070	0.02
Shell Tickness, mm	0.274	0.268	0.264	0.273	0.278	5.91
Haugh Unity	87.89	88.59	87.84	88.21	88.66	1.70

[1]*Total amino acids.*
[2]*Digestible amino acids.*
[3]*Corn and soybean meal.*
[4]*Corn, Soybean meal, meat and bone meal.*
[5]*Corn, Soybean meal, meat and bone meal and feather meal.*

Table 9.
Egg quality of Japanese quails fed diets based on Total amino acids (AAT), digestible amino acids (AAD), and different ingredients in its composition.

The mean values obtained in the serum concentration of plasma uric acid (**Table 11**) show a significant interaction between the formulation bases and the ingredients utilized. CST diets differed significantly from the others, presenting lower plasma uric acid concentrations.

Varibless	Base formulation		Ingredients			
	TAA[1]	DAA[2]	CS[3]	CS[4]	MSCP[5]	CV(%)
N intake (g/bird/day)	0.728	0.762	0.746	0.721	0.715	11.61
N excretion (g/bird/day)	0.788b	0.768b	0.703b	0.625b	0.943a	12.77
N retention (g/bird/dia)	−0.059	−0.006	0.043	0.096	−0.228	15.78
Excreted N: N intake (%)	108.24	100.78	94.23	106.8	101.72	13.58
N retained: N intake (%)	−8.24b	−0.78ab	5.77a	−6.80b	−1.72b	19.28

[1]*Total amino acids.*
[2]*Digestible amino acids.*
[3]*Corn and soybean meal.*
[4]*Corn, Soybean meal, meat and bone meal.*
[5]*Corn, Soybean meal, meat and bone meal and feather meal.*

Table 10.
Nitrogen balance and plasma uric acid of laying Japanese quails fed different bases and formulation ingredients in their compositions.

Variables	TAA[1]			DAA[2]		
		CSM	CSM		CSM	CSMF
	CST	T	FT	CSD	D	D
Starter diets cost (US$/kg)	0.435	0.42	0.42	0.43	0.415	0.415
		0.15				
Feed intake(1–21. kg/bird)	0.178	0.155	0.164	0.151	0.156	0.157
Cost of feeding (1–21. US$/bird)	0.07	0.06	0.06	0.06	0.06	0.06
Growth diets cost (U$/kg)	0.42	0.41	0.41	0.42	0.41	0.40
Feed intake (22–42. kg/bird)	0.387	0.4	0.392	0.388	0.379	0.387
Cost of feeding (22–42. US$/bird)	0.162	0.162	0.16	0.162	0.155	0.155
Laying diets cost (US$/kg)	0.40	0.39	0.38	0.39	0.385	0.37
Feed intake in laying stage (kg/bird)	2,185	2,076	2,031	2,087	2,020	2,079
Cost of feeding (84–133 days US$/bird)	0.88	0.82	0.77	0.83	0.78	0.77
Total feed intake (all stages)	2.74	2.63	2.58	2.62	2.55	2.62
Total cost feeding (US$/bird)	1.11	1.05	1.00	1.065	1.00	0.995
Egg production /BIRD	76.52	72.17	74.56	73.91	72.50	73.31
Gross income (US$/bird)	2.29	2.16	2.23	2.21	2.17	2.44
Gross margin (U$/bird)	1.18	1.11	1.23	1.145	1.17	1.44
Relative gross margin (%)	100	94.48	102.77	97.64	98.03	100.59

Table 11.
Production economic analysis of Japanese quails in initial stages, growth and laying stage.

The diets based on corn and soybean meal showed a slight elevation in cost about those that contained meat and bone and feather meals, regardless of the base formulations (**Table 11**).

Formulation diets based on TAA or DAA did not significantly influence WG; however, FC was higher with DAA, demonstrating that even if there is a remarkable increase in intake, diets formulated with DAA are more efficient at the utilization of the nutrients in this phase. Birds during the starter phase deposited less dietary protein compared with older birds. This may be associated with the low FI and reduced digestive efficiency due to the physical limitation of the gastrointestinal tract, which elevates the protein degradation rate to compensate for the high energy requirements of young birds [6]. The performance results of this phase also demonstrate that among the ingredients utilized, birds fed diet CSMF exhibited higher FI and WG than those on diet CS. Since proteins from animal origin by-products have a higher biological value and greater amino acid availability, there was a higher uptake of amino acids for the synthesis of muscle proteins; this is important for the development of this tissue. In the starter phase, the initial weight of Japanese quails increases seven-fold due to hypertrophy of muscles, the pectorals in particular, and the growth of bones and viscera [7]. However, Moura et al. [8] concluded that although the quail increases its body mass by approximately 10 times in the first 21 days, this growth is attributed to a greater synthesis of bone tissue more than muscle hypertrophy itself.

However, when utilizing animal-origin by-products in poultry diets, one must be very careful as to the quality of these ingredients and their nutritional compositions, since several factors can affect the amino acid availability. The digestibility coefficients of amino acids in meat and bone and feather meals can be influenced by the system in which they are processed, temperature, cooking time, drying, and the proportions of components within the product.

Shin and Vohra [9] demonstrate that Japanese quails reared for laying eggs exhibit a low tissue-deposition capacity after 35 days from birth due to the elevated mass of eggs produced daily. The early maturation of quails (35–42 days of age) leads to the need for feeding programs that maximize the growth rate and body development, which makes it possible for quails to reach the ideal weight at sexual maturity and ensures better uniformity of the flock during the laying phase [10].

According to Silva [11], birds during this stage are physiologically delicate since their body growth is impaired while the structures involved in egg production grow faster. Undernourished birds in this phase will be less productive, showing a shorter production peak and cycle at the laying phase. Important physiological alterations, such as an increase in the weight of the liver, ovary, and oviduct, are highly dependent on the level of available nutrients. Thus, diets formulated for growing Japanese quails must meet the requirements for them to absorb the nutrients necessary for the development of the reproductive tract, to be ready to begin laying eggs.

Formulations based on TAA significantly improved performance about higher FI compared with formulations based on DAA, however, no difference was identified for WG nor FC. This demonstrates that diet formulation based on DAA is more efficient at using nutrients in the starter and growth phases of Japanese quails. The maintenance of adequate body weight in layers during these initial phases is important since it interferes with the protein requirements of the bird. An adequate supply of protein for layers allows birds to reach sexual maturity with body weight and reserves capable of bearing the production phase without compromising the reserves [12]. This can be explained by the nutritional conditions established during the growth period influencing bird performance during the production phase. However, most previous studies have addressed the nutritional requirements of birds in the production phase, whereas research aiming to determine the requirements in the starter and growth phases is scarce [10].

Base formulations and ingredients utilized did not affect the performance of the quails ($P > 0.05$; **Table 7**). Wang and Parsons [13] results conform with the data presented here, with the diets for birds formulated with DAA performing equally as efficiently as those formulated with TAA. Evaluating the effect of ingredients utilized on bird performance indicated that diets containing CST exhibited higher FI and egg production. Diets with CSMT had higher consumption but lower production. In diets containing CSMFT, the FI values were the lowest recorded. However, their egg production was similar to the diets with CST. Freitas et al. [14] verified that quails display lower FI and egg weight with increasing metabolizable energy; however, they did not observe an influence of metabolizable energy on egg production. The average weight of a quail egg is 10.3 g, accounting for approximately 8% of the live weight of the bird; this is considerably greater compared with that of 3.5% in chickens. This indicates there is a major nutrients demand egg synthesis. Protein and energy content of the diet is a fundamental nutritional factor in egg weight determination [15, 16, 17]. Assessing the morphometric characteristics of the oviduct of quails fed diets of increasing protein levels, Artoni et al. [18] concluded that the birds receiving a diet containing 24%CP, the highest level, exhibited an increased thickness of the magnum gland, isthmus, and uterus. Consequently, egg weight and shell thickness increased. Furthermore, Ribeiro et al. [19] demonstrated that quails-fed diets containing 23% protein exhibited a greater FI, egg weight, egg mass, FC, and egg components (yolk and albumen) in comparison with the quails fed on 20%.

At 20% CP in the diets, bird performance remained stable for all the assessed variables when TAA and DAA base formulations were compared. Umigi [20] concluded that whilst in the laying phase, birds can have diet CP reduced by up to 5%without having impairing performance and egg quality, provided that the diets are properly supplemented with the essential limiting amino acids.

Base formulations and the ingredients used in the shell percentage significantly influenced egg quality (**Table 8**). No significant differences were observed for any of the egg quality variables studied (**Table 9**).

The results showed that diets based on DAA containing CSMFT were superior, demonstrating better use of the nutrients associated with the formation of the shell, such as calcium and phosphorus. Accordingly, birds can produce more resistant eggs with longer durability, allowing farmers to have better marketability of viable eggs. Similarly, the diets containing CSMFT are statistically superior in terms of this variable, demonstrating that the inclusion of these ingredients in the diet improves the quality of the shell of Japanese quail eggs. Dietary phosphorus (P) levels can alter the production and quality of eggs; however, the P level that promotes the highest shell quality may not be the one that promotes the highest egg production [21]. Plasma calcium (Ca) can exist when bound to the protein's albumin and globulin as well as when unattached, referred to as ionized (Ca2+). Half of the plasma Ca exists in the ionized form, and the other half bound to proteins. According to Ito [22], during the calcification period, the Ca deposited in the shell originates from two sources: dietary and from bones. Even if the birds consume an adequate amount of Ca from their diet, approximately30%–40% of the Ca deposited in the shell originates from the medullary bones. However, the utilization of Ca from the skeleton can be increased even with low levels of ingested Ca. The greater the dependence of Ca provision from the skeleton, the lower the amount deposited in the shell, thus resulting in eggs with thin shells and little resistance to cracking. The low-quality eggshell also presents a potential risk of bacterial contamination of the egg [23]. Among several factors that affect eggshell quality, the source and levels of Ca from the diet must be highlighted since the eggshell is almost totally comprised of calcium carbonate [22].

The average results of the digestibility assay are presented in **Table 10**. The diets that contained CSMFT presented greater nitrogen excretion. Such results can be explained by the low quality of the protein in the feather meal in these diets, which generated a reduction in the digestibility and absorption of amino acids. There were no significant differences between the retention of N by birds and formulation bases nor ingredients utilized. The excretion of N was higher than the intake in birds fed CSMFT and diets formulated based on TAA and DAA. This occurs in birds at more advanced ages due to the high desquamation of the intestinal epithelium, reducing the capacity of nutrient absorption.

That a reduction in protein content and the supplementation of the diet with industrial amino acids can substantially decrease N excretion. Excretion of N can be significantly reduced by an amino acid balance that meets the requirements of birds but with minimum excess, and especially through the supply of these nutrients in the digestible form [24].

The composition of excreta is directly influenced by the nutritional composition of the diet consumed by birds. Thus, when formulating diets with high CP levels based on TAA, with the utilization of a margin of safety or by the unfamiliarity of the nutritional composition of the feeds, a high protein content in the excreta is expected [25]. According to Lemme [26], the greater the inclusion of raw materials of low amino acid digestibility based on formulations of TAA, the less reliable the estimation of bird performance. This makes the poultry industry use an onerous margin of safety at the offer of nutrients. The largest portion of N excreted by birds is related to the material that was not digested and the excessive amino acids left after requirements for maintenance and egg production have been met [4].

CST diets differed significantly from the others, presenting lower plasma uric acid concentrations. This may be explained by the diets containing only CST having a higher amino acid digestibility than those containing the animal-origin by-products (CSM, CSMF), thus increasing the usage efficiency of these amino acids. Schmidt et al. [27] state that approximately 60%–80% of the uric acid excreted in birds is N. Uric acid is related to kidney and liver metabolism and is the main source of excretion of nitrogenous bases. Uric acid excretion is utilized as an indicator of protein quality ingested by birds; less protein is deposited in the muscle and more uric acid is excreted when birds receive low-quality protein in the diet, or when they are subjected to amino acid imbalance [28].

The diets based on corn and soybean meal showed a slight elevation in cost about those that contained meat and bone and feather meals, regardless of the base formulations (**Table 11**). This accrual may be attributed to the utilization of soybean meal being higher and the supplementation of industrial amino acids being lower in these diets to meet the amino acid requirement during this phase. The diets which contained the inclusion of the meat meals, however, resulted in a lower cost when compared with those using vegetable protein sources. The cost of the diet varied by 7.5% (US$0.03) and the cost of feeding had a variation of 11.94% (US$0.10). The impact on the reduction of soybean meal in the diet was 7.45%. In diet CSMFT, in which meat meal is included, the variation was 2%, whilst for the feather meal, it was 2.28%. In diet CSMFD, this inclusion was 3.35% and 1.81% for the meat and feather meals, respectively. The cost of feeding per bird varied by 10.85%, showing the lowest discrepancies in the diets that received the inclusion of the meals. Diet CSMFD was the most efficient.

The number of eggs produced during the laying phase (84 days) varied by 5.68% among the treatments, with a gross income at around US$2.58 per bird during the experimental period. The data on the relative gross income of the treatments were obtained through the percentage of the gross income of diet CST, formulated with corn and soybean meal and based on TAA. Diet CSMFT showed to be more efficient, reaching 1.94% over the relative gross income of diet CST. The relative gross income of diet CSMFD, however, was just 0.28% below that of diet CST.

4. Conclusions

Improved efficiency at FC was observed at the starter phase for the diets formulated based on DAA and when protein ingredients of animal origin were used. From 22 to 42 days of age, diets formulated based on DAA did not influence the performance of birds, appearing to be similar to those of the animals which received diets based on TAA. Diets formulated based on DAA for Japanese quails can be utilized with the same efficiency as diets based on TAA. The partial replacement of soybean meal by animal-origin by-products such as meat bone meal and feather meal for Japanese quails is possible, however, more research is needed to evaluate the inclusion of these ingredients in the different base formulations.

Conflict of interest

The authors declare no conflict of interest.

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