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ANIMAL PRODUCTION

Nutritional plans and ambient temperature on the growth curves of Japanese quails

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ABSTRACT: This study estimated the growth of body, carcass, primal cuts, edible offal, and feathers of Japanese quail reared in two thermal environments, receiving three nutritional plans, from one to 39 days of age. A total of 576 one-day-old female chicks (*Coturnix japonica*) with an average initial weight of 7.51±0.75g/bird were evaluated in a completely randomized design with a 3 × 2 factorial arrangement (three nutritional plans × two temperatures). The animals were housed in two climatic chambers, at 25 ºC and 35 ºC, using 12 replications with eight birds per experimental unit. Nutritional plans (NP) were as follows: NP1: one diet from 1-21days and another from 22-39 days; NP2: one diet from 1-14 days and another from 15-39 days; and NP3: a single diet from 1-39 days. The growth curves and growth rates of body, carcass, primal cuts, feathers, and edible offal were evaluated using the Gompertz mathematical model. Quail fed NP3 showed higher growth curves and rates for body, carcass, drumstick +thigh, and feather. There was an effect on maturity rate, which was lowest in quail housed at 35 ºC. Among the animals kept at 25 ºC, the group fed NP3 exhibited the highest growth rate and breast weight. The nutritional plan consisting of a single diet offered from 1 to 39 days, formulated based on the tables for Japanese and European quail, is the most suitable for estimating the growth curves (Gompertz model) of Japanese quail housed at 25 ºC or 35 ºC.
Key words: ambience, body weight, growth rate, quail farming.

Planos nutricionais e temperatura ambiente nas curvas de crescimento de codornas japonesas

RESUMO: Objetivou-se estimar o crescimento corporal, carcaça, cortes nobres, vísceras comestíveis e penas de codornas japonesas criadas em dois ambientes térmicos e alimentadas com três planos nutricionais de um a 39 dias. Foram utilizadas 576 pintainhas (*Coturnix japônica*), fêmeas, com um dia de idade, com peso médio inicial 7,51 ± 0,75g/ave, distribuídas em delineamento inteiramente casualizado em esquema fatorial 3 × 2 (três planos nutricionais x duas temperaturas), alojadas em duas câmaras climáticas de 25º e 35 ºC, com 12 repetições e oito aves por unidade experimental. Os planos nutricionais foram: plano nutricional um (PN1) – uma dieta de 1-21 dias e uma dieta de 22-39 dias; plano nutricional dois (PN2) – uma dieta de 1-14 dias e uma dieta de 15-39 dias; e plano nutricional três (PN3) - dieta única de 1-39 dias. Foram avaliadas as curvas e taxas de crescimento corporal, carcaça, cortes nobres, penas e vísceras comestíveis, através do modelo matemático de Gompertz. Codornas alimentadas com PN3 apresentaram maiores curvas e taxas de crescimento corporal, de carcaça, coxa + sobrecoxa e penas. Houve efeito para taxa de maturidade, sendo inferior para codornas alojadas em 35 ºC. Nas aves mantidas em 25 ºC, observou-se maior taxa de crescimento e peso de peito nas codornas alimentadas com PN3. O plano nutricional composto por uma única dieta ofertada durante o período de um a 39 dias, formulado com base nas recomendações das tabelas para codornas japonesas e europeias, é o mais indicado para estimar curvas de crescimento no modelo de Gompertz de codornas japonesas alojadas em 25 ºC ou 35 ºC.
Palavras-chave: ambiência, coturnicultura, peso corporal, taxa de crescimento.

INTRODUCTION

Quail farming has grown in recent years and stands out in the poultry sector owing to the current technical production and the new forms of marketing eggs (MENDONÇA et al., 2022). Different recommendations exist regarding the formulation of diets for Japanese quail: either using one single diet throughout the rearing period; or two diets, one for the starter and another for the grower phase (SILVA & COSTA, 2009; ROSTAGNO et al., 2017).

External factors, such as effective ambient temperature, also influence bird growth. Heat stress, one of the main factors limiting production, directly affects animal welfare, meat quality, production, and egg quality (GOEL, 2021).

Body growth curves can be used as selection criteria for Japanese quail (KARADAVUT et al., 2017). Among the non-linear mathematical models applied to determine growth curves, the Gompertz function is a tool employed by nutritionists to characterize the genetic potential of birds and adequately describes

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the growth of Japanese quail (SILVA et al., 2016). Because this model provides a biological explanation for its parameters, its estimates are more accurate and essential to better understand the growth of quail. As a result, it contributes to genetic improvement programs and allows maximizing production systems for these animals (CARVALHO et al., 2020).

Curves generated from animal growth data generally have a sigmoidal structure divided into two phases: the first stage is expressed as the inflection point, where growth rate is maximum. Then, it starts to decline in the second stage up to the point of zero growth (i.e., asymptote: the highest value that can be theoretically reached for an individual when all conditions are suitable) (KARADAVUT et al., 2017).

In this scenario, research must be undertaken to provide updated information on the growth of Japanese quail when subjected to different factors such as nutritional plans and housing temperatures. Therefore, this study proposed to estimate the growth of body, carcass, cuts, offal, and feathers of Japanese quail reared in two thermal environments and receiving three nutritional plans up to 39 days of age.

MATERIALS AND METHODS

A total of 576 one-day-old female Japanese quail (*Coturnix japonica*) with an average initial weight of 7.51 ± 0.75g/bird were housed in galvanized-wire cages equipped with feeders and drinkers. The battery cages were located in 2×4m climatic chambers with temperature and humidity control (76 ± 2%), equipped with 250-W hoods (heating source) placed one meter from the battery and one meter from the floor; exhaust fans; and an air conditioner to maintain a temperature of 25 °C. The lighting program adopted was 24 h of daily light, using fluorescent bulbs.

A completely randomized experimental design with a 3×2 factorial arrangement (three nutritional plans × two temperatures), with the animals being housed in two climatic chambers (25 or 35±2 ºC). Twelve replications were used, with eight birds per experimental unit. The nutritional plans for the Japanese quail were as follows: NP1 - in the phases from 1-21 and 22-42 days of age, by following the recommendations of SILVA & COSTA (2009); NP2 - from 1-14 and 15-35 days of age, as recommended by ROSTAGNO et al. (2017); and NP3 - from 1-42 days of age, as per SILVA & COSTA (2009) (Table 1). Feed and water were available *ad libitum* throughout the experimental period.

The birds were weighed and slaughtered every three days, from the first to the 39th day of age, to determine the weights of carcass, primal cuts, edible offal, and feathers. At the end of each three-day period, after a six-hour fast, two quail from each group were weighed individually, then euthanized and bled to extract the cuts. Then, they were plucked to determine feather weight and eviscerated to obtain the weights of carcass, offal, and cuts (breast and drumstick + thigh).

Growth curves were determined by adopting the mathematical model proposed by Gompertz (1825), which expresses body weight as a function of the animal's age: $Wt = Wm.exp(-exp(-b(t-t^{*})))$, where Wt = estimated weight (g) at time t (days); Wm = weight (g) at maturity; t = age (days); b = maturity rate (g/day); and t^{*} = age at maximum growth (days). The quail's growth rate (GR) was estimated by the derivative of the Gompertz function: $GR = Wm.b.(exp(-exp(-b.(t-T)))).(exp(-b.(t-T)))$.

The estimates of weight at maturity (Wm), maturity rate (b), and age at maturity (t^{*}) were subjected to analysis of variance using the ANOVA procedure of SAS software (Statistical Analysis System, version 9.4). Means were compared by the F-test and Tukey's test ($P < 0.05$).

RESULTS

Body and feathers

The nutritional plans did not affect the parameters of the Gompertz model (Table 2) for body weight at 25 ºC, but did at 35 ºC, in which case NP2 (213.50^{B} g) provided a lower weight at maturity (Wm) than NP1 and NP3 (231.20^{A} and 229.60^{A} g, respectively). Only birds that received NP2 had a lower body weight (P=0.001) at 35 ºC compared with the environment at 25 ºC (213.50^{b} vs. 235.2^{a}g, respectively).

Maturity rate (b)for body weight decreased in the birds reared at 25 ºC, relative to those in the 35 ºC environment: from 0.058^{a} to 0.052^{b} g/day (NP1); 0.057^{a} to 0.055^{b} g/day (NP2); and 0.057^{a} to 0.053^{b} g/day (NP3), respectively. Nutritional plan 1 delayed age at maturity by 1.3 days in the quail in the hot environment (20.21^{b} vs. 21.55^{a} days) ($P < 0.022$).

The quail under NP3 and reared at 25 ºC exhibited the highest growth rate for body weight at 20 days (5.03 g/day), which was followed by a decline (Figure 1a). Feather weight did not respond to the interaction or separate effect of nutritional plans, but there was a reduction in weight and age at

Table 1- Percentage and calculated composition of the experimental diets.

Ingredient	-------------------NP1------------------		-------------------NP2--------------		NP3
	1 to 21 days	21 to 39 days	1 to 14 days	15 to 39 days	1 to 39 days
Grain corn	54.568	59.272	56.267	58.753	56.809
Soybean meal 46%	39.647	34.841	36.280	36.577	38.758
Meat and bone meal	3.726	1.295	5.725	1.968	0.000
Soybean oil	0.294	2.083	0.000	0.000	1.269
Dicalcium phosphate	0.000	0.640	0.501	1.132	1.050
Calcitic limestone	0.692	0.807	0.394	0.680	1.046
Common salt	0.477	0.520	0.353	0.442	0.543
DL-methionine	0.148	0.145	0.104	0.074	0.149
L-lysine	0.074	0.021	0.000	0.000	0.000
Choline chloride	0.150	0.150	0.150	0.150	0.150
Vitamin supplement[1]	0.150	0.150	0.150	0.150	0.150
Mineral supplement[2]	0.050	0.050	0.050	0.050	0.050
Zinc bacitracin	0.010	0.010	0.010	0.010	0.010
Anticoccidial agent	0.005	0.005	0.005	0.005	0.005
Antioxidant	0.010	0.010	0.010	0.010	0.010
Total	100.00	100.00	100.00	100.00	100.00
---Nutritional composition---					
Metabolizable energy (kcal/kg)	2,900	3,050	2,900	2,900	2,950
Crude protein (%)	25.00	22.00	24.40	23.00	23.00
Dig. lysine (%)	1.250	1.050	1.095	1.034	1.104
Dig. methionine + cystine (%)	0.800	0.740	0.740	0.693	0.770
Dig. methionine (%)	0.487	0.451	0.436	0.394	0.469
Calcium (%)	0.850	0.750	1.092	0.911	0.800
Available phosphorus (%)	0.320	0.300	0.513	0.428	0.310
Sodium (%)	0.240	0.240	0.205	0.214	0.240
EB[3], mEq/kg	238.26	212.43	229.53	221.91	224.77

[1]Vitamin supplement/kg: Vit. A 13,440,000 IU; Vit. D 3,200,000 IU; Vit. E 28,000 mg/kg; Vit. K 2,880 mg/kg; Thiamine 3,500 mg/kg; Riboflavin 9,600 mg/kg; Pyridoxine 5,000 mg/kg; Cyanocobalamin 19,200 mcg/kg; Folic Acid 1,600 mg/kg; Pantothenicacid 25,000 mg/kg; Niacin 67,200 mg/kg; Biotin 80,000 mcg/kg; Antioxidant 0.40 g/kg. [2]Mineral Supplement/kg: Mg 150,000 ppm; Zn 140,000 ppm; Fe 100,000 ppm; Cu 16,000 ppm; I 1,500 ppm; Se 600 ppm. [3]Electrolyte balance.

Table 2 - Estimation of Gompertz equation parameters for body weight and feathers in Japanese quail receiving different nutritional plans (NP) at different housing temperatures (T).

Plan	-----------Wm (g)------------		---------b (g/day)--------		----------t^* (days)-------			--------------p-value--------------		
	25 ºC	35 ºC	25 ºC	35 ºC	25 ºC	35 ºC		NP	T	NP×T
--Body weight--										
NP1	230.20	231.20^{A}	0.058^{a}	0.052^{b}	20.21^{b}	21.55^{a}	Wm	0.092	0.022	0.014
NP2	235.20^{a}	213.50^{bB}	0.057^{a}	0.055^{b}	20.47	20.25	b	0.375	0.001	0.054
NP3	237.60	229.60^{A}	0.057^{a}	0.053^{b}	20.76	21.50	t^*	0.075	0.009	0.021
SEM	6.60		0.001		0.520					
---Feathers---										
NP1	7.83^{a}	7.60^{b}	0.163	0.172	9.05^{a}	8.97^{b}	Wm	0.626	0.047	0.452
NP2	8.00^{a}	7.26^{b}	0.152	0.168	10.33^{a}	9.12^{b}	b	0.710	0.310	0.956
NP3	7.97^{a}	7.73^{b}	0.152	0.162	10.31^{a}	9.59^{b}	t^*	0.067	0.049	0.355
SEM	------------0.383-------------		-----------0.022----------		-----------0.649----------					

NP1: SILVA & COSTA (2009), phases from 1-21 and 22-39 days; NP2: ROSTAGNO et al. (2017), phases from 1-14 and 15-39 days; NP3: SILVA & COSTA (2009), phase from 1-39 days of age. ns: not significant ($P > 0.05$). Means followed by different uppercase letters in columns and lowercase letters in rows differ ($P < 0.05$) statistically by Tukey's test. Wm: weight at maturity; b: maturity rate; t^*: age at maximum growth.

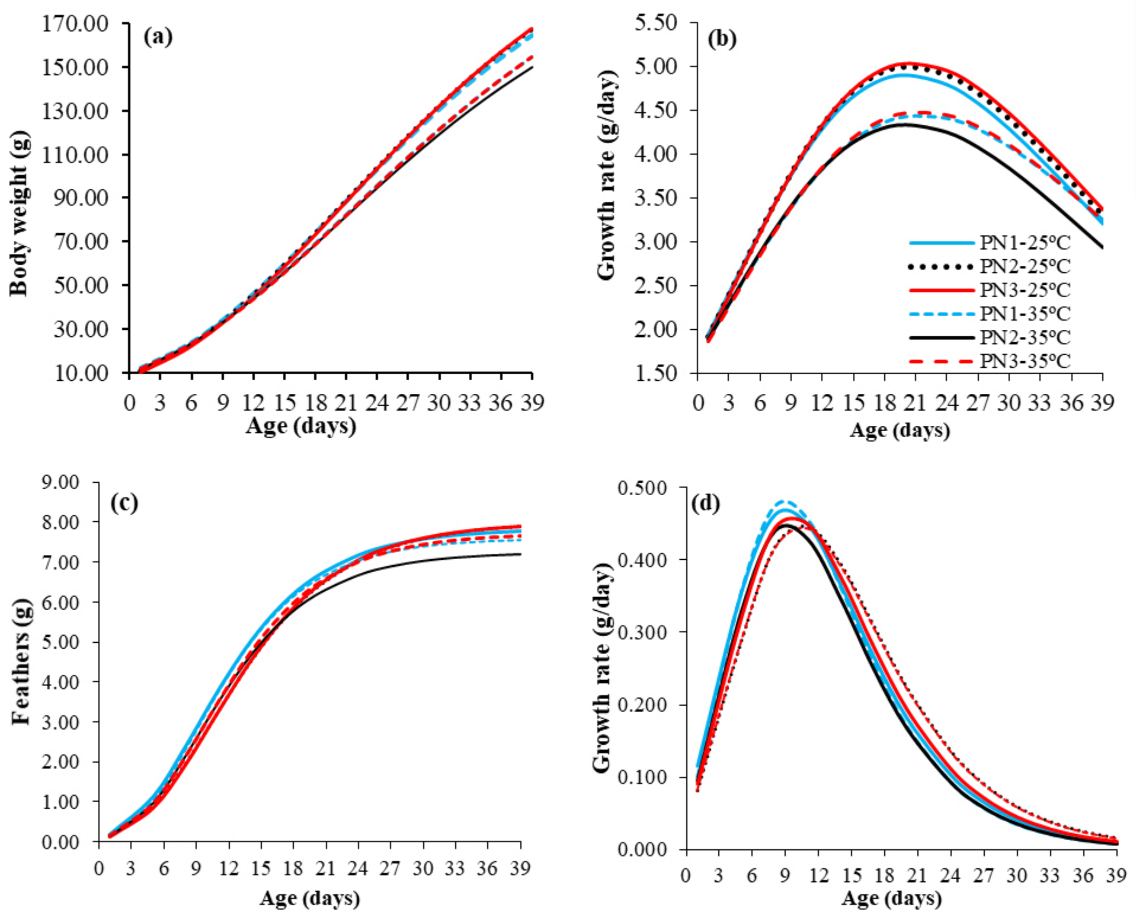

Figure 1 - Growth curve (a) and growth rate (b) of body weight; and growth curve (c) and growth rate (d) of feathers in Japanese quail receiving different nutritional plans and subjected to different housing temperatures. NP1: Silva & Costa (2009), phases from 1-21 and 22-39 days; NP2: Rostagno et al. (2017), phases from 1-14 and 15-39 days; NP3: Silva & Costa (2009), phase from 1-39 days of age. NP1: Silva & Costa (2009), phases from 1-21 and 22-39 days; NP2: Rostagno et al. (2017), phases from 1-14 and 15-39 days; NP3: Silva & Costa (2009), phase from 1-39 days of age.

maximum growth (t^*) at 35 ºC. The quail that received NP3 had the highest growth curve, and those under NP1 showed a higher feather growth rate at both temperatures (Figure 1c and 1d).

Carcass, breast, and drumstick + thigh

Carcass Wm was higher in the quail fed NP2 and NP3 (117.90^A and 120.80^A, respectively) than in the animals that received NP1 (109.93^B). There was also an effect of ambient temperature. For the three nutritional plans, carcass Wm was higher at 25 ºC than at 35 ºC (Table 3). Birds under NP1 exhibited higher carcass Wm values at 25 ºC (by about 11.37%) than those reared at 35 ºC.

Birds that received the diet with NP1were earlier-developing for carcass weight (by around 1.5 days) in relation to those fed NP3. Figure 2 illustrates the growth curves and rates, and shows that NP2 and NP3 provided higher weights. The Gompertz equation parameters Wm and b for breast and Wm for drumstick +thigh (Table 3) indicate that Japanese quail housed at 25 ºC have higher weight at maturity and maturity rate, that is, they reach maximum growth of their body, breast, and

Table 3 - Estimation of the parameters of the Gompertz equation for carcass, breast, and drumstick + thigh weights in Japanese quail receiving different nutritional plans (NP) at different housing temperatures (T).

Plan	------------Wm (g)-----------		-------b (g/day)--------		----------t^* (days)----------			---------------p-value-------------		
	25 ºC	35 ºC	25 ºC	35 ºC	25 ºC	35 ºC		NP	T	NP×T
	---Carcass---									
NP1	109.93^{aB}	88.63^{bB}	0.090^{b}	0.105^{a}	15.31^{aB}	13.09^{b}	Wm	0.001	0.001	0.065
NP2	117.90^{aA}	92.40^{bA}	0.085^{b}	0.100^{a}	16.34^{aA}	13.94^{b}	b	0.051	0.001	0.754
NP3	120.80^{aA}	92.63^{bA}	0.082^{b}	0.099^{a}	16.83^{aA}	13.88^{b}	t^*	0.001	0.001	0.198
SEM	2.27		0.004		0.339					
	--Breast--									
NP1	37.57^{a}	32.03^{b}	0.095	0.102	16.50	15.01	Wm	0.113	0.001	0.167
NP2	40.70^{a}	32.57^{b}	0.090^{b}	0.105^{a}	17.68^{a}	15.65^{b}	b	0.054	0.001	0.204
NP3	38.20^{a}	30.33^{b}	0.096^{b}	0.116^{a}	16.82^{a}	14.49^{b}	t^*	0.051	0.001	0.566
SEM	1.212		0.005		0.675					
	-----------------------------------Drumstick + Thigh--------------------------------------									
NP1	23.43^{a}	19.93^{bB}	0.101^{b}	0.113^{a}	13.55^{a}	12.04^{bB}	Wm	0.023	0.001	0.325
NP2	24.56^{a}	21.66^{bAB}	0.093^{b}	0.103^{a}	14.65^{a}	13.42^{bAB}	b	0.054	0.026	0.391
NP3	24.17	22.33^{A}	0.097	0.099	14.35	13.60^{A}	t^*	0.004	0.001	0.514
SEM	------------0.930------------		--------0.006-----------		-----------0.571-----------					

NP1: SILVA &; COSTA (2009), phases from 1-21 and 22-39 days; NP2: ROSTAGNO et al. (2017), phases from 1-14 and 15-39 days; NP3: SILVA & COSTA (2009), phase from 1-39 days of age. ns: not significant (P > 0.05). Means followed by different uppercase letters in columns and lowercase letters in rows differ (P < 0.05) statistically by Tukey's test. Wm: weight at maturity; b: maturity rate; t^*: age at maximum growth.

drumstick+thigh early. The nutritional plans affected (p=0.001) the t^* parameter for drumstick+ thigh weight in the heat-stressed environment, with NP3 providing higher values than NP1 (13.60^{A} vs. 12.04^{B} days) and no differences occurring for breast weight. Nutritional plans 3 and 1 also resulted in higher drumstick+ thigh growth rates (0.870 and 0.862 g/day), compared with NP2 (0.839 g/day) (Figure 2f).

Heart, gizzard, and liver

The nutritional plans did not affect any parameters of the Gompertz model (Table 4) for heart or gizzard weight. Heat stress influenced the decrease in the growth curve of the gizzard (Wm and t^*) and liver (Wm) (P=0.001) of quail fed NP1.

Maturity rate for liver weight under NP2 decreased from 0.091^{a} to 0.065^{b} g/day between the environment at 25 ºC and the other at 35 ºC, that is, heat stress reduced maturity rate. However, this was not the case for the other nutritional plans, i.e., even at high temperatures, maturity rate was similar to that found in the 25 ºC environment.

Quail fed NP1 at 25 ºC had the highest growth rates (Figure 3b and 3f): for heart, at 14 days (0.056 g/day), and liver at 17 days (0.167 g/day). At 25 ºC, NP3 provided the highest gizzard growth rates (Figure 3d) at 8 days (0.126 g/day). Birds fed NP1 (35 ºC) showed higher growth rates of heart and gizzard (0.04 and 0.09 g/day); and those under NP3, of liver (0.13 g/day) (Figure 3).

DISCUSSION

The use of different nutritional recommendations influences bird growth. The quail fed NP2 showed a decrease in Wm at 35 ºC. Weight at maturity is directly related to factors extrinsic to production, e.g. effects of nutrition and ambient temperature that influence the shape of the growth curve, which may display different asymptotic weights (GOTUZZO et al., 2019).

The feather growth curve showed earlier development in NP3 (Figure 1), and the same was observed for its growth rate in NP1 (at 25 ºC and 35 ºC), whereas lower results were seen in NP2. This fact can probably be explained by the higher level of digestible methionine + cystine present in the NP1 (1 to 21 days = 0.800%; 22 to 42 days = 0.740%) and NP3 (0.770%) treatments, compared with NP2 (1 to 14 days = 0.740%; 15 and 35 days = 0.693%), since sulfur amino acids (methionine and cystine) are destined mainly for protein synthesis,

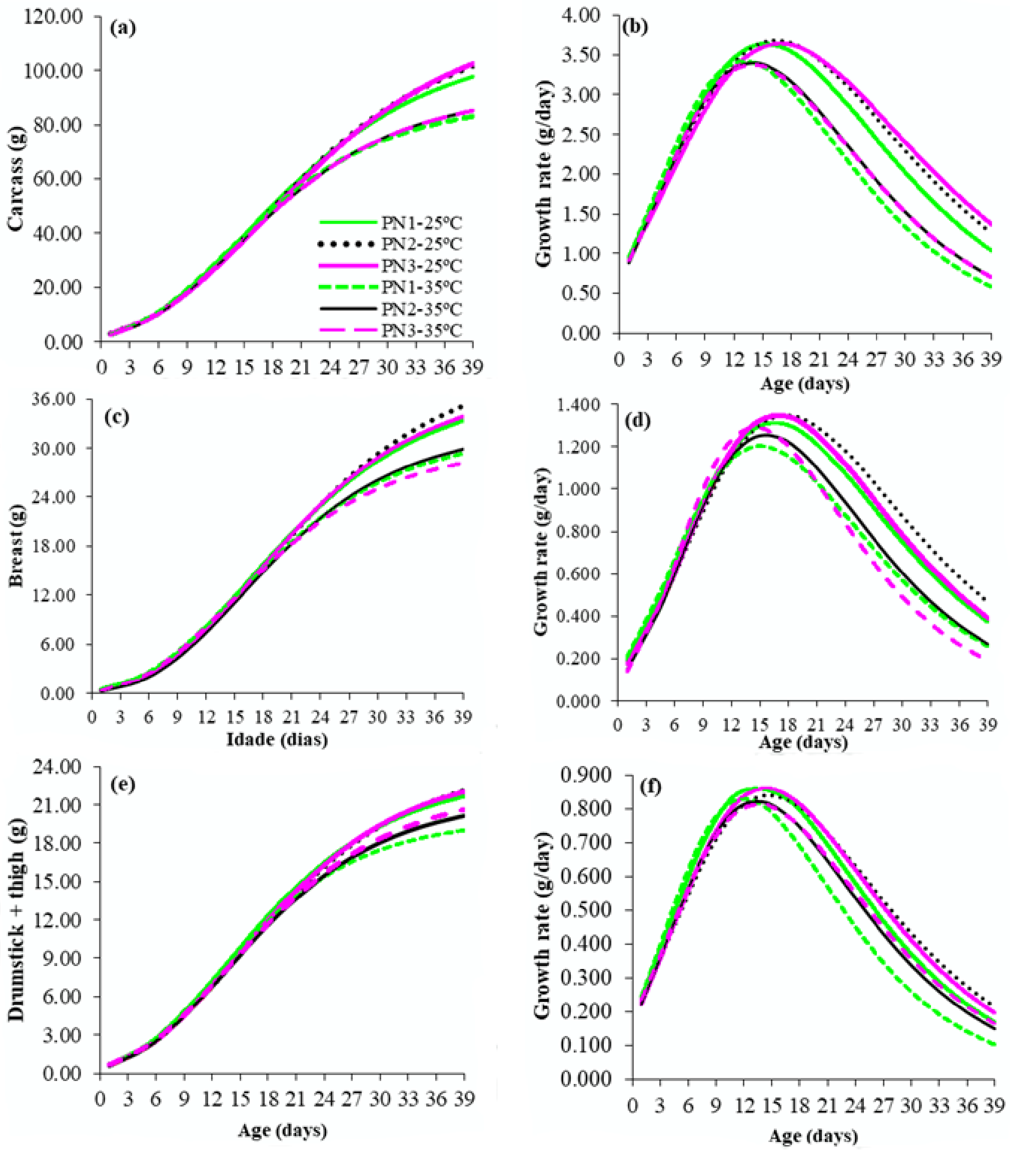

Figure 2 - Growth curve (a) and growth rate (b) of carcass; growth curve (c) and growth rate (d) of breast; and growth curve (e) and growth rate (f) of drumstick + thigh in Japanese quail receiving different nutritional plans and subjected to different housing temperatures. NP1: SILVA & COSTA (2009), phases from 1-21 and 22-39 days; NP2: ROSTAGNO et al. (2017), phases from 1-14 and 15-39 days; NP3: SILVA & COSTA (2009), phase from 1-39 days of age.

with methionine being the first limiting factor for birds. Together with cystine, methionine acts in the formation of feathers (MORAES et al., 2021), which explains the lower feather growth in NP2.

Moreover, heat stress leads to the production of excessive amounts of reactive oxygen species (ROS), causing oxidative stress, which damages cell phospholipid membranes and other macromolecules (MIAO et al., 2021). In addition to worsening feed conversion, it reduces carcass quality and weight, resulting in economic impacts (PU et al., 2020). Methionine also acts on the metabolic route of glutathione synthesis, which acts to reduce oxidative stress. Therefore, according to the results, the impact of the high temperature may have been minimized in the birds that received NP1 and NP3.

Table 4 - Estimation of the parameters of the Gompertz equation for weight of edible offal in Japanese quail receiving different nutritional plans (NP) at different housing temperatures (T).

Plan	---------Wm (g)--------		--------b (g/day)---------		-----------t^{*} (days)-------			---------------p-value-----------		
	25 ºC	35 ºC	25 ºC	35 ºC	25 ºC	35 ºC		NP	T	NP×T
	---Heart--------------------------------------									
NP1	1.80	1.53	0.085	0.073	15.09	14.25	Wm	0.682	0.101	0.190
NP2	1.80	1.63	0.083^{a}	0.062^{b}	14.63	15.03	b	0.526	0.045	0.197
NP3	1.96	1.50	0.073	0.074	15.66	12.60	t^{*}	0.648	0.088	0.115
SEM	0.135		0.009		1.335					
	--Gizzard--------------------------------------									
NP1	3.73^{a}	3.00^{b}	0.085	0.083	9.52^{a}	6.44^{b}	Wm	0.979	0.001	0.118
NP2	3.40	3.00	0.098	0.082	8.40	7.22	b	0.341	0.384	0.372
NP3	3.43	3.03	0.100	0.084	8.06	6.97	t^{*}	0.888	0.004	0.109
SEM	0.279		0.202		1.273					
	---Liver--									
NP1	8.00^{aA}	5.40^{b}	0.057^{B}	0.055	21.60^{A}	21.01	Wm	0.001	0.001	0.103
NP2	5.47^{B}	5.10	0.091^{aA}	0.065^{b}	15.71^{B}	18.51	b	0.001	0.020	0.104
NP3	6.47^{B}	5.57	0.060^{B}	0.064	18.69^{A}	19.33	t^{*}	0.002	0.221	0.207
SEM	---------0.452----------		-----------0.006----------		-----------1.569----------					

NP1: SILVA & COSTA (2009), phases from 1-21 and 22-39 days; NP2: ROSTAGNO et al. (2017), phases from 1-14 and 15-39 days; NP3: SILVA & COSTA (2009), phase from 1-39 days of age. ns: not significant (P > 0.05). Means followed by different uppercase letters in columns and lowercase letters in rows differ (P < 0.05) statistically by Tukey's test. Wm: weight at maturity; b: maturity rate; t^{*}: age at maximum growth.

Birds fed NP2 and NP3 showed higher carcass Wm and growth curve (Table 3 and Figure 2, respectively). Parameters Wm and b of breast and Wm of drumstick + thigh (Table 3) indicate that Japanese quail receiving NP3 and housed at 25 ºC have higher weight at maturity and maturity rate, i.e. the maximum growth of these cuts is reached early in those birds. These characteristics indicated that birds in an environment at 25 ºC are earlier-developing than those housed at 35 ºC, that is, both nutrition and environmental conditions can affect the growth curve parameters (KAPLAN & GÜRCAN, 2018).

High temperatures can induce several adaptive physiological changes that result in changes in the size of organs (PORTO et al., 2021) such as the heart, gizzard, and liver (Table 4 and Figure 3). The lower gizzard weight was likely due to the reduction in feed intake and consequent decrease in mechanical movements to break down the food particles for digestion. The reduction in the organs of the birds at 35 ºC may also be due to the high metabolic rate and consequent high heat production caused by the internal organs.

The parameters of the growth model and their biological significance are very useful for inferring and accurately predicting economic information related to maturity and the inflection point when compared with results of simple analyses of growth characteristics such as weight at different ages (DUDUSOLA et al., 2019). Bird growth is accelerated up to a certain age - represented by the inflection point of the curve (obtained by the t^{*} parameter in the function)-, at which growth rate is maximum. After the inflection, birds slow down their growth, gradually reducing the daily gain rates to reach adult weight (Wm), which causes the curve to stabilize (SAKOMURA & ROSTAGNO, 2016).

The estimated growth curves can contribute to future research and decision-making on feed management, thus helping to define the choice of nutritional plan. In addition, the changes caused by the increase in ambient temperature also indicated that birds have different responses to each nutritional recommendation for each temperature.

CONCLUSION

The nutritional plan formulated based on the tables for Japanese and European quail (single diet) in the period from one to 39 days is the most suitable for estimating the growth curves (Gompertz model) of Japanese quail housed at 25 ºC or 35 ºC.

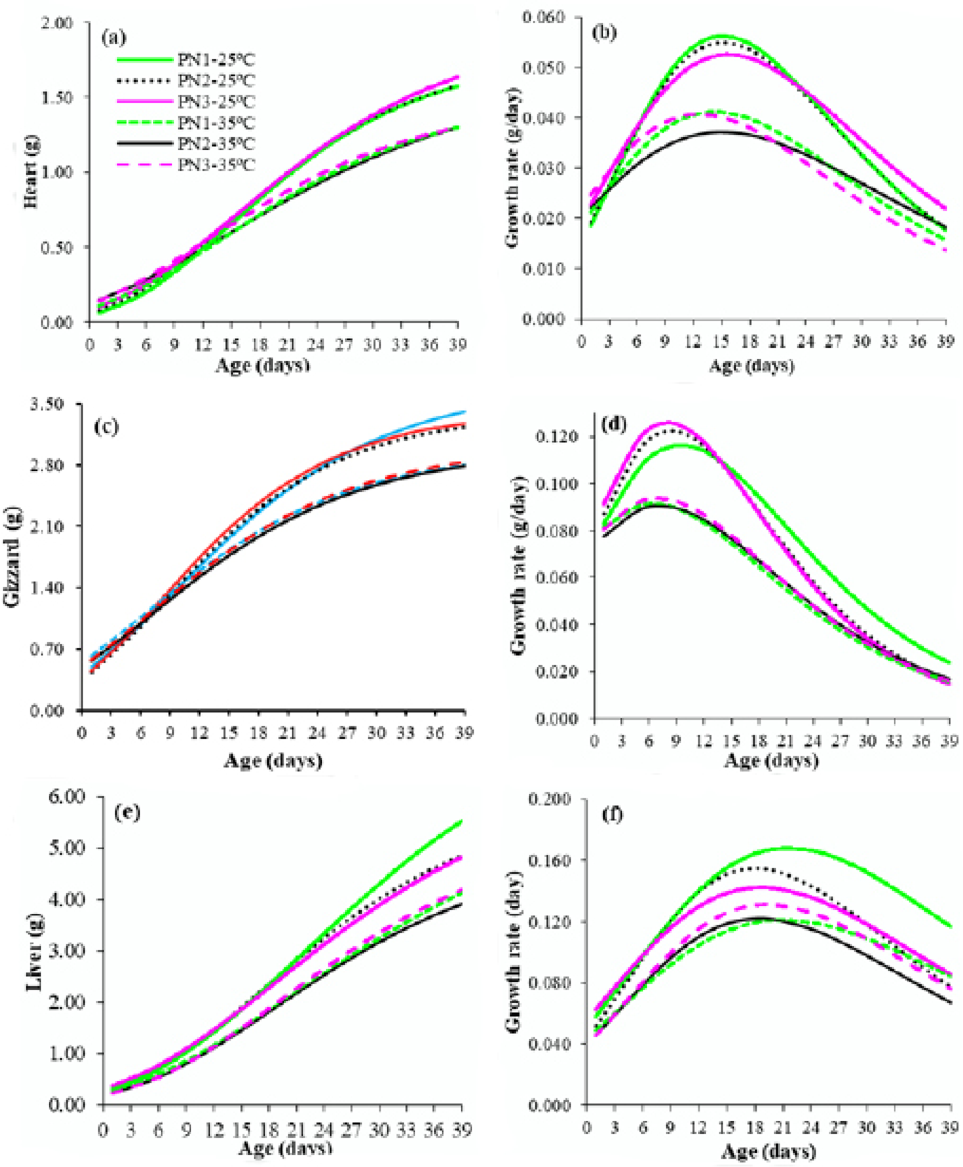

Figure 3 - Growth curve (a) and growth rate (b) of heart; growth curve (c) and growth rate (d) of gizzard; and growth curve (e) and growth rate (f) of liver in Japanese quail receiving different nutritional plans and subjected to different housing temperatures. NP1: SILVA & COSTA (2009), phases from 1-21 and 22-39 days; NP2: Rostagno et al. (2017), phases from 1-14 and 15-39 days; NP3: SILVA & COSTA (2009), phase from 1-39 days of age.

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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 design 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 Federal University of Paraíba (Protocol No. 5665070319).

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