ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.4, p.292-298, 2022
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n4p292-298

Does environmental enrichment improve performance, morphometry, yield and weight of broiler parts at different ages?[1]

Enriquecimento ambiental melhora desempenho, morfometria, rendimento e peso das partes de frangos em diferentes idades?

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HIGHLIGHTS:

The use of perch did not change feed intake, weight gain and feed conversion.
The morphometry and weight of the drumstick + thighs, feet and chest increased in perch from the last week of rearing.
The use of a perch showed a differentiated and hyperalometric growth for the drumstick + thighs and chest.

ABSTRACT: The inclusion of environmental enrichment in conventional broiler rearing can increase mobility, bone mass and muscle. This research aimed to evaluate the use of environmental enrichment in the rearing of broilers at different ages and its influence on performance, morphometry, yield and weight of the parts. It was used the completely randomized design in split-plot scheme, being the plots the treatments presence (T1) and absence (T2) of environmental enrichment and the subplots the broiler ages (1, 7, 14, 21, 28, 35 and 42 days), with 56 chicks in each treatment (T1 and T2). Data obtained were analyzed by the linear effect model of fixed effects and compared by Tukey's test of means. The animals were raised in a controlled environment, divided into four boxes with dimensions: 1.5 × 1.0 × 0.7 m, containing rice straw bed. In T1 a ladder with a perch on top was used, distributed every 1.5 m^2. Environmental enrichment used did not influence broiler's zootechnical performance. Broilers' morphometric properties, parts weight and body weight increased due to environmental enrichment and, improvement was observed in chicks rearing's final phase. The environmental enrichment was beneficial for muscle and bone mass gain in the main commercial parts of the chicken carcass, in addition to reducing the allometric coefficient of the breasts in chickens.

Key words: poultry farming, perch, chicks movement

RESUMO: A inclusão do enriquecimento ambiental na criação convencional dos frangos de corte pode causar aumento na mobilidade, massa óssea e músculos. O objetivo desta pesquisa foi avaliar o uso do enriquecimento ambiental na criação de frangos de corte em diferentes idades e sua influencia no desempenho, morfometria, rendimento e peso das partes. Foi utilizado o delineamento inteiramente casualizado em esquema de parcelas subdivididas, sendo que, nas parcelas foram alocados os tratamentos presença (T1) e ausência (T2) de enriquecimento ambiental e nas subparcelas as idades dos frangos (1, 7, 14, 21, 28, 35 e 42 dias), com 56 aves em cada tratamento (T1 e T2). Os dados obtidos foram analisados pelo modelo linear de efeitos fixos e comparados pelo teste de médias de Tukey. Os animais foram criados em ambiente controlado, dividido em quatro boxes com dimensões: 1,5 × 1,0 × 0,7 m, contendo cama de palha de arroz. Em T1 utilizou-se uma escada com poleiro no topo distribuída a cada 1,5 m^2. O uso de enriquecimento ambiental não influenciou no desempenho zootécnico dos frangos de corte. As propriedades morfométricas, peso das partes e o peso corporal dos frangos de corte aumentaram, devido ao uso do enriquecimento ambiental; essa melhoria foi observada na fase final de criação das aves. O enriquecimento ambiental foi benéfico para ganho de massa muscular e óssea nas principais partes comerciais da carcaça de frango, além de reduzir o coeficiente alométrico dos peitos dos frangos.

Palavras-chave: avicultura de corte, poleiro, movimentação das aves

• Ref. 251919 – Received 07 May, 2021
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• Accepted 30 Oct, 2021 • Published 11 Nov, 2021
Editors: Lauriane Almeida dos Anjos Soares & Carlos Alberto Vieira de Azevedo

Introduction

Industrial poultry farming has reached the maximum zootechnical performance to achieve the best profitability indices. However, the current facilities have low complexity, homogeneous rearing environment, and present several factors that can compromise broiler chicken welfare (Norring et al., 2016). According to Weeks et al. (2000), broiler chickens remain seated for approximately 86% of their lives, and such inactivity causes skeletal disorders in their legs, as well as lameness, and pod dermatitis - these conditions get worse as they age (Knowles et al., 2008).

Inserting environmental enrichment, such as barriers between feeder and drinker (Bizeray et al., 2002a), and perches and litter boxes (Simsek et al., 2009) in poultry plants did not show any significant difference in zootechnical performance in comparison to the conventional production. Several studies have shown that broilers' legs health conditions have been improved due to environmental enrichment using (barriers, perch, ramp, and bales), since these chicks have their motivation to move around (Bizeray et al., 2002b; Bailie & O'Connell et al., 2015; Bailie et al., 2018).

It is important questioning whether environmental enrichment adoption influences zootechnical performance, morphometry, carcass yield, body weight, and parts' weight in order to reduce production losses in poultry farming due to broilers' smaller contact with bed and more exercising in the facilities. Based on the afore mentioned considerations, the aim of the current research was to evaluate the use of environmental enrichment in the rearing of broilers at different ages and its influence on performance, morphometry, yield and weight of the parts.

Material and Methods

The study was carried out in São Paulo University - Luiz de Queiroz College of Agriculture (Piracicaba City, São Paulo State, Brazil).The region where the research was conducted is located at the geographical coordinates 22° 42' 30" S and 47° 38' 00" W and at an altitude of 546 m. It was approved by the Animal Ethics Committee (CEUA) of the same university, under protocol n. 2016/10.

In total, 112 broiler chicks belonging to Cobb strain were used in the study. They were housed at density of 12 chick's m^{-2} and 128 chicks were used for replacement. The birds were reared for two production cycles (42 days of life). Replacement animals were subjected to the same rearing conditions (treatment, density, diet, and climatic conditions) as the ones in the treatments throughout the entire experimental time. The research followed a randomized experimental design in split-plot scheme, being the plots constituted by the treatments (T1 - presence of environmental enrichment and T2 - absence of environmental enrichment) and the subplots constituted by broiler's ages (1, 7, 14, 21, 28, 35 and 42 days). The Eq. 1 shows the statistical model of the experimental design.

$$Y_{ij} = \mu + \tau_i + e_i + \beta_j + (\tau\beta)_{ij} + \varepsilon_{ij} \quad (1)$$

where:

Y_{ij} - value observed in i^{th} treatment and j^{th} subplot j;

μ - mean value;

τ_i - effect of the i^{th} factor A (environmental enrichment);

e_i - residual of the plots;

β_j - effect of the j^{th} factor B (age);

$(\tau\beta)_{ij}$ - interaction between the i^{th} factor A and j^{th} factor B; and,

ε_{ij} - residual of the subplots.

The trials were divided into four boxes presenting the following dimensions:1.5 m in length, 1.0 m in width, and 0.7 m in height (Figure 1A). Animals were randomly distributed in the boxes, which had rice straw bedding and access to water and feed ad libitum. The feeding program was divided into three phases and made available based on the chicks' age, namely: initial, growth, and final phases, as recommended by Rostagno et al. (2017).

The environmental enrichment model and design (a ladder with a perch on top) was chosen due to previous studies that have taken into account its cost, ease of assembly, and acquisition by producers (Ohara et al., 2015).The perch was made of pinewood and had the shape of a stick with rounded edges. This material was chosen because it is light and has low conductivity and thermal capacity, which favors thermal insulation. The assessed model design was based on maintaining the environmental enrichment model at the height of 5 cm, for a time interval ranging from 1 to 21 days, which was increased 10 cm, within the time interval ranging from 22

A.

B.

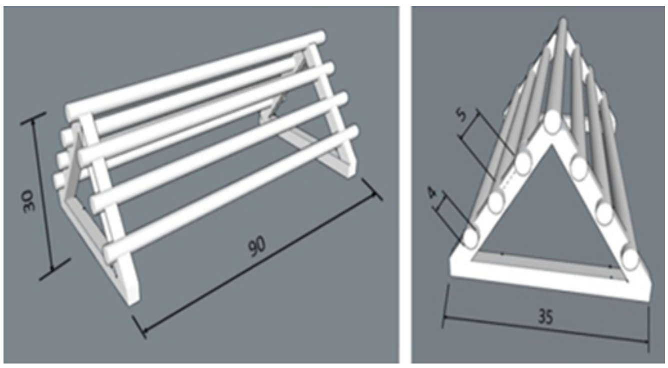

Figure 1. Boxes in the climatic chamber (A) and environmental enrichment model used in the research with dimensions of: 90 cm length, 35 cm width, 30 cm height, 4 cm thickness and 5 cm spacing between steps (B)

to 42 days, based on Ohara et al. (2015). Occupancy density was 15 cm per bird and thickness was set at 4 cm (RSPCA, 2013). The following dimensions were adopted in order to meet research needs: 90 cm in length, 35 cm in width, and 30 cm in height (Figure 1B).

The microclimatic variables were controlled through a thermally insulated climate chamber (controlled environment) with automatic control of air temperature, relative air humidity, ventilation rate and light program, meeting the thermoneutral needs of birds, according to Cobb (2012) (Table 1). The light program for ages 0-35 days (18 hours light and 6 hours dark) and 35-42 days (16 hours light and 8 hours dark) and the ventilation rate was 0.04-0.21 m^3 of air s^{-1} kg of chick. In addition, within the controlled environment, two dataloggers from the Hobo® brand were installed, in order to ensure constant control of the temperature and relative humidity of the air.

Zootechnical performance (weight gain, feed conversion, and feed consumption) were assessed on a weekly basis. Replacement broilers were used as a replicate only in the zootechnical performance analyses. Replacement animals used as replicate during the experimental time was based on the methodology developed by Frutosa et al. (2018) and Bang et al. (2018). However, the morphometric properties, parts weight, body weight and parts yield (allometric coefficient) were not used in replacement animals for analysis. For the evaluations of morphometric properties (drumstick + thighs and feet), weight of parts (drumstick + thighs, breasts and feet), body weight and parts yield (drumstick + thighs and breast) eight chicks per treatment were euthanized at the ages of 1, 7, 14, 21, 28, 35 and 42 days, through cervical dislocation, following the animal welfare norms. Drumstick + thighs, feet, and breasts were removed after euthanasia through veterinary incision, which was made with the aid of a clinical scalpel.

The morphometric properties of feet containing bone, musculature, and skin were measured and recorded (tarsometatarsus diameter and length from the end of the nail of the third finger to the end of the tarsometatarsus), as well as drumstick + thighs (cut length along the bone, musculature, and skin), by using the right and left sides of each chick, in separate. Parts' length and diameter were recorded by using a Digimess digital caliper (0.02 mm accuracy). Broiler chickens' feet, drumstick + thighs, and breast and body weight were recorded before the chicks were euthanized. Parts, body, and feed weight measurements were taken in a semi-analytical scale, at 0.1 g precision.

Response variables were assessed through analysis of variance, which was carried out according to the linear model

Table 1. Temperature and relative humidity of the air ranges ideal for the broilers used in the research, according to Cobb (2012)

Age (days)	Air temperature (°C)	Relative air humidity (%)
1	32-33	30-50
7	29-30	40-60
14	27-28	50-60
21	24-26	50-60
28	21-23	50-65
35	19-21	50-70
42	19-21	50-70

of fixed effects. Assumptions were validated based on residual plots, Shapiro-Wilk normality tests, and Hartley test, to assess variance homogeneity. Treatments were compared through Tukey test ($p \leq 0.05$). In addition, it was performed a linear regression analysis of the ages (1 to 42 days) of broiler chickens for morphometry and weight of parts in different treatments. SAS statistical package (2010) was used for the assessments.

Carcass and parts' yield was assessed by taking into account the study on the allometric growth determined for different parts (drumstick + thighs and breasts) in comparison to live body weight by using Eq. 2, as proposed by Huxley (1932).

$$Y = aX^b \text{ or } \ln Y = \ln a + b \ln X \quad (2)$$

where:
- Y - body part weight (kg);
- X - live body weight (kg);
- a - the intercept;
- ln - natural logarithm; and,
- b - allometry coefficient.

Growth is isometric when b = 1, which means that body part growth was equal to body weight growth, based on Sabbioni et al. (2016) and Piedade et al. (2018). When b < 1 body part growth was lower than body growth, allometry was negative or hypoallometry. When b > 1, body part growth was faster than body growth, allometry was positive or hyperallometry.

Results and Discussion

Broiler chicken weight gain, feed conversion and consumption did not show any difference (p = 0.063; p = 0.097 and p = 0.950) due to the presence (T1) or absence of environmental enrichment (T2). These results corroborated findings by Bizeray et al. (2002b) and Simsek et al. (2009), in which there were no observable differences in feed consumption and conversion, and in weight gain of broilers subjected to conventional environment and the ones subjected to enriched environment. However, these authors have mentioned that the use of environmental enrichment does not reduce production, but improves bird welfare levels.

The morphometric evaluation showed difference ($p \leq 0.0001$) in interactions between treatments (T1 and T2) and the broilers' age when it comes to feet and drumstick + thighs (Table 2). The significant changes ($p \leq 0.0001$) in feet' diameter and length, and in drumstick + thighs length were observed in the last rearing weeks (35 and 42 days), when environmental enrichment resulted in higher values for the assessed parameters.

The highest mean response variables recorded were the following: feet diameter (8.95 and 8.01 mm kg^{-1} of live weight); feet length (75.70 and 67.42 mm kg^{-1} live weight); and drumstick + thighs length (89.35 and 87.36 mm kg^{-1} live weight), respectively (Table 2). On the other hand, natural reduction of the following ratios was expected to happen as chicks aged: leg diameter and length kg^{-1} of live weight and drumstick + thighs length kg^{-1} of live weight. Such natural reduction was significant in the first week, but it decreased after chicks' development.

Table 2. Morphometry of the feet and drumstick + thighs of broilers subjected to treatments (T1 - presence of environmental enrichment and T2 - absence of environmental enrichment) at different breeding ages

Treatments	Chicken age (days)						
	1	7	14	21	28	35	42
	Diameter of broiler chicken feet (mm kg^{1} live weight)						
T1	87.53 aA	31.28 bA	18.40 cA	11.58 dA	9.81 dA	8.95 dA	8.01 dA
T2	86.26 aA	31.43 bA	17.22 cA	10.66 dA	9.73 dA	6.53 dB	6.40 dB
CV (%)	9.91						
DF Residual	202						
	Length of broiler chicken feet (mm kg^{1} live weight)						
T1	1204.49 aA	372.70 bA	179.94 cA	112.67 cdA	85.62 dA	75.70 dA	67.42 dA
T2	1198.27 aA	372.50 bA	172.18 cA	105.40 cdA	89.54 cdA	67.69 dB	59.18 dB
CV (%)	5.038						
DF Residual	202						
	Length of broiler chicken drumstick + thigh (mm kg^{1} live weight)						
T1	1332.93 aA	416.54 bA	234.57 cA	134.25 dA	105.09 dA	89.35 dA	87.36 dA
T2	1329.30 aA	410.95 bA	229.48 cA	127.45 dA	98.77 dA	81.79 dB	76.20 dB
CV (%)	4.147						
DF Residual	202						

CV - Coefficient of variation; DF - Degrees of freedom; Means with different lowercase letters on each line and uppercase letters in each column differed from each other by the Tukey test, at p ≤ 0.05

The use of environmental enrichment increased and improved the morphometric properties, parts weight and body weight of broilers. This was due to the greater muscle and bone development of chicks that practiced more physical activities (using the ladder with a perch) during the production cycle. Similar results to this research were verified by Bizeray et al. (2002a) and Reiter & Bessei (2009), who observed an increase in muscle and bone development, due to the greater mobility of broilers that used environmental enrichment (barriers between feeder and drinker). The literature provided no studies about environmental enrichment use and its influence on broilers' morphometry, parts' weight (drumsticks + thighs, chest and feet), and carcass yield throughout the rearing period. However, several researches have already assessed the improvements observed in the legs of chicken subjected to environmental enrichment used (perch, ramp, and bales) due to increased stimulus for exercising (Bailie & O'Connell et al., 2015; Bailie et al. 2018). The perches on the ladder improved birds' skeletal and muscular development (Yan et al., 2014).

Broilers' parts (feet, drumstick + thighs, and breast) weight and body weight showed significant difference (p ≤ 0.0001) in interactions between treatments (T1 = presence of environmental enrichment and T2 = conventional system or absence of environmental enrichment) and age (Table 3).

The effect of environmental enrichment was evident in every assessed variable (feet, drumstick + thighs, and body) from the 35th rearing day on, except for variable "breast weight", whose difference was observed at the 28th day. The highest mean values were verified at T1 and ages 35 and 42 days, with: feet weight of 19.35 and 19.00 g kg^{-1}, body weight; drumstick + thighs weight of 109.22 and 115.39 g kg^{-1} body weight; chest weight of 231.70, 251.05 and 266.98 g kg^{-1} body weight, and body weight of 2.02 and 2.41 g kg^{-1} body weight, respectively (Table 3).

Table 3. Broiler chickens' body and parts' weight at different treatments (T1 - presence of environmental enrichment and T2 - absence of environmental enrichment) and rearing age

Treatments	Chicken age (days)						
	1	7	14	21	28	35	42
	Broiler chicken's feet weight (g kg^{1} live weight)						
T1	29.98 aA	21.29 bA	21.01 bA	20.37 bcA	19.45 bcA	19.35 bcA	19.00 cA
T2	29.17 aA	20.95 bA	20.14 bcA	19.52 cdA	18.55 cdA	18.10 cdB	17.24 dB
CV (%)	18.45						
DF Residual	202						
	Broiler chicken's drumstick + thighs weight (g kg^{1} live weight)						
T1	87.22 dA	94.33 cA	96.48 cA	104.53 bA	106.36 bA	109.22 bA	115.39 aA
T2	88.19 dA	94.56 cA	97.57 cA	103.09 bcA	105.61 abA	107.88 aB	109.54 aB
CV (%)	18.17						
DF Residual	202						
	Broiler chicken's breast weight (g kg^{1} live weight)						
T1	39.93 gA	124.80 fA	167.99 eA	204.40 dA	231.70 cA	251.05 bA	266.98 aA
T2	44.28 fA	120.17 eA	173.53 dA	199.64 cA	213.10 cB	242.34 bB	256.05 aB
CV (%)	8.98						
DF Residual	90						
	Broiler chicken's body weight (kg^{1} live weight)						
T1	0.04 fA	0.18 fA	0.46 eA	0.94 dA	1.42 cA	2.02 bA	2.41 aA
T2	0.04 fA	0.18 fA	0.52 eA	1.00 dA	1.42 cA	1.77 bB	2.10 aB
CV (%)	19.67						
DF Residual	90						

CV - Coefficient of variation; DF - Degrees of freedom; Means with different lowercase letters on each line and uppercase letters in each column differed from each other in the Tukey test, at p ≤ 0.05

Environmental enrichment increased and improved broiler parts' weight (feet, drumsticks + thighs and chest) and body weight. This fact can be explained by the greater muscle and bone development of broilers, due to their greater mobility. Physical activity increases the mechanical load that operates on the bone tissue, due to external forces and muscle contractions; this helps in bone remodeling and bone weight increase (Shipov et al., 2010; Regmi et al., 2016). Therefore, the use of environmental enrichment for laying hem facilities resulted in increased exercising levels that have, in their turn, improved bone and muscle formation (Fleming et al., 2006; Rodriguez-Navarro et al., 2018). Similar results were observed in other animals (Aido et al., 2015) who have been subjected to studies on the bone-biomechanics field. It is important highlighting that chicks' natural perching achieved by using perches, platforms and barriers, promotes bone and muscle structure improvement, in addition to reduce contact between legs and bedding, as well as acts as mechanism to make the use of available spaces more intense (Bizeray et al., 2002a; Norring et al., 2016).

Differences in morphometry and weight (feet, drumstick + thighs and breast) were significant at broiler rearing's final phase (35 and 42 days); therefore, this result is assumingly related to the availability and, consequent, use of perches in broiler rearing. Although some authors have stated that broilers tend to decrease the response to environmental enrichment due to aging, its use in the initial rearing phase can have effects on adulthood. On the other hand, some authors stated that the use of perches by broiler breeders increased when the chickens aged (Gebhardt-Henrich et al., 2018).

The environmental enrichment assessed in the current study increased the chick' body weight. Aksit et al. (2017) and Gebhardt-Henrich et al. (2018) also observed higher body weight in birds who had access to perches. On the other hand, Bizeray et al. (2002b) did not observe any significant change in chick' body weight due to environmental enrichment used.

Linear regressions of broiler age for morphometry, part weight and body weight in the different treatments (T1 and T2) were significant ($p \leq 0.0001$) (Table 4). However, only the coefficients of variation of weights (body and breast) were below the recommended (CV < 30%), therefore, the other variables presented heterogeneity and high data dispersion. Thus, it can be said that only the weights (body and chest) obtained high R^2. However, breast weight presented very similar R^2 values at T2 and T1 and the highest R^2 for body weight was 0.925 for T1. Based on body weight the growth is allometric, but the coefficients for the parts will be smaller. Therefore, there is an inadequacy of linear regression to identify the growth of parts.

Broiler chicken parts' allometric coefficient (drumstick + thighs and breasts) was higher than 1, either for environmental enrichment presence (T1) or absence (T2) (Table 5). This finding evidenced hyperallometric growth - parts grew faster than the body. Each part had a different growth speed in comparison to body weight increase, which caused changes

Table 4. Linear regression of ages (1 to 42 days) of broilers for morphometry and weight of parts at different treatments

Treatments/ Parts' morphometry	T1 - presence of environmental enrichment			T2 - absence of environmental enrichment		
	Feet diameter	Feet length	Drumstick + thigh length	Feet diameter	Feet length	Drumstick + thigh length
R^2	0.581	0.556	0.587	0.609	0.551	0.578
CV (%)	43.56	44.83	43.23	42.06	45.07	43.70
F-test	152.29	137.62	156.26	171.37	135.04	150.58
Equation	Y = -0.34*x+29.83	Y = -0.03*x+28.08	Y = -0.03*x+29.47	Y = -0.40*x+30.69	Y = -0.03*x+28.89	Y = -0.03*x+29.73
Treatments/ Parts' weight	**T1 - presence of environmental enrichment**			**T2 - absence of environmental enrichment**		
	Feet	Drumstick + thighs	Breast	Feet	Drumstick + thighs	Breast
R^2	0.322	0.312	0.860	0.404	0.409	0.874
CV (%)	55.40	55.80	25.28	51.92	51.70	23.56
F-test	52.18	49.85	318.53	74.65	76.23	375.07
Equation	Y = -1.64*x+56.43	Y = +0.64*x-43.34	Y = +0.17*x-10.24	Y = -1.88*x+59.59	Y = +0.73*x-53.21	Y = +0.17*x-10.93
Treatments/ Weight	**T1 - presence of environmental enrichment**			**T2 - absence of environmental enrichment**		
	Broiler body			Broiler body		
R^2	0.925			0.901		
CV (%)	18.23			20.91		
F-test	661.92			490.71		
Equation	Y = +15.12*x+4.96			Y = +16.91*x+4.16		

CV - Coefficient of variation; R^2 - Coefficient of determination; * - Significant at $p \leq 0.05$ by F-test

Table 5. Effect of treatments and rearing stages (ages) on broilers' carcass yield based on the allometric growth (b) of the parts (Y) in comparison to body weight (X) by using the following equation: ln Y = lna + b lnX

Age (days)	T1 lna	T1 b	T1 R^2	T2 lna	T2 b	T2 R^2	T1 ln	T2 ln
			Y - Drumstick + thighs				X - Body weight	
1-42	4.060	1.06	0.999	4.047	1.05	0.998	6.359	6.347
1-21	3.101	1.04	0.998	3.160	1.03	0.998	5.465	5.510
21-42	5.152	1.08	0.999	5.083	1.14	0.987	7.375	7.324
			Y - Breast				X - Body weight	
1-42	4.511	1.41	0.992	4.523	1.49	0.995	6.359	6.347
1-21	3.321	1.53	0.994	3.302	1.52	0.991	5.465	5.510
21-42	5.893	1.18	0.998	5.939	1.54	0.999	7.375	7.324

T1 - Presence of environmental enrichment; T2 - Absence of environmental enrichment; Y - Body part weight (kg); X - Live body weight (kg); a - The intercept; ln - Natural logarithm; b - Allometry coefficient in features, anatomical structure, and body composition in adulthood (Huxley, 1932; Sabbioni et al., 2016; Piedade et al., 2018).

Based on results recorded for variable carcass yield, it was observed that the breast has a growth much above the body growth, with a small advantage for animals with absence of environmental enrichment (T2), according to the value of the allometric coefficient (1.49) at ages 1-42 days. However, when the comparison is made from half of the growth phase until slaughter (weight) age (21-42 days), it was verified considerable difference between treatments with greater impetus for animals with absence of environmental enrichment (T2), according to the allometric coefficient of 1.54. Such results were not observed for the drumstick + thigh, in separate.

The most "balanced" growth was recorded for parts of animals subjected to environmental enrichment (T1) when the complete data set (breast and drumstick + thighs) was assessed in combination to allometry. Therefore, it was recorded that the use of environmental enrichment (T1) caused bird parts to have growth rate closer to body growth rate, mainly breast growth rate at rearing's final phase.

The result showed that a wider distributed impulse can lead to good yield in the development of other relevant parts (drumstick + thighs and feet) in the context of chicken carcass production.

Results in the current research showed that the use of environmental enrichment (a ladder with a perch on the top) improved the quality of birds' parts (drumstick + thighs, chest, and feet) since they presented the highest mean lengths, diameters, and parts and body's weights. The effects of these benefits were observed in bird rearing's final phase (35 and 42 days).

Conclusions

1. The use of environmental enrichment did not influence broiler's zootechnical performance.
2. Broilers' morphometric properties, parts weight and body weight increased in the final phase due to environmental enrichment use.
3. The environmental enrichment was beneficial for muscle and bone mass gain in the main commercial parts of the chicken carcass, in addition to reducing the allometric coefficient of the breasts in chickens.

Acknowledgments

The authors thank the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) for granting a scholarship and research funding (protocol n. 2016/10769-8).

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