

Performance and Welfare of Laying Hens Raised on Floor in Relation to Different Housing Densities

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ABSTRACT. This study analyzed the productive performance, egg quality and physiological and behavioral parameters of laying hens at different housing densities in a cage-free system, following animal welfare guidelines and improvements in animal housing in intensive systems. 252 Novogen Brown laying hens, 52 weeks old and with an average weight of $1,740 \pm 0.11$ kg, were used over 63 days, divided into three periods of 21 days. The study adopted a completely randomized experimental design, with four treatments and seven replications. The housing densities tested were: 6 birds box⁻¹ ($0.406 \text{ m}^2 \text{ bird}^{-1}$), 8 birds box⁻¹ ($0.305 \text{ m}^2 \text{ bird}^{-1}$), 10 birds box⁻¹ ($0.244 \text{ m}^2 \text{ bird}^{-1}$) and 12 birds box⁻¹ ($0.203 \text{ m}^2 \text{ bird}^{-1}$). The data were analyzed for normality of residuals, homogeneity of variance and independence of errors, using linear and quadratic regression models for each variable. In cage-free poultry production systems, housing densities of 6 to 8 birds per box can be used without affecting performance, egg quality, physiological or behavioral parameters of the hens.

Keywords: laying hens; welfare; cage-free; alternative systems.

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Introduction

Alternative production systems are expanding worldwide, driven by increasing interest in ensuring animal welfare and increased productivity. These approaches aim to create environments that enhance the quality of life for birds, allowing for the expression of their natural behaviors and providing more space for exploration (Reis et al., 2019).

The floor production system, or "cage-free" system, can be characterized by raising birds freely inside the barn without access to outdoor areas, providing more space for movement and exploration, thus aligning with good animal welfare practices (Moura et al., 2022).

Some aspects related to the *cage-free* system still require further investigation, such as the appropriate stocking density within each area, bird behavior, and the effects on egg quality (Valentim et al., 2019). This is because behavior is closely linked to animal welfare, while egg quality is a variable directly associated with economic return both are key factors for the successful large-scale implementation of this system (Kunzler et al., 2023).

Despite the growth of these alternative systems, issues such as bird density still require discussion, as it is crucial to determine the appropriate number of birds to ensure welfare, optimized performance, and, consequently, profitability, especially in hot climates where temperature poses additional challenges for birds (Netto et al., 2018).

In this context, research continues to be developed to improve alternative systems, providing added value to the final product. This approach aims to ensure that throughout the rearing period, animals achieve maximum economic return with minimal production costs (Netto et al., 2023).

Densities in modern poultry farming are interconnected with animal performance. It is known that when many animals are placed in a smaller area, there is a decrease in performance due to hierarchy, as well as conditioning animals to limited movement in the environment, suppressing their natural behavior, and intensifying signs of stress (Barros & Souza Junior, 2021).

It is important to highlight that in hot climates, birds face greater challenges related to thermal comfort. Most cage-free facilities do not have automated systems for environmental control, relying instead on natural methods, such as tree shading, to promote air circulation and reduce direct solar radiation (Dias et al., 2016).

In this context, research efforts are justified in seeking appropriate stocking densities that ensure the physical and physiological well-being of the birds.

Therefore, the objective of the present study was to evaluate the rearing of laying hens in floor systems at different densities by assessing their influence on their behavioral repertoire, animal performance, physiological parameters, and egg quality.

Material and methods

The experiment was conducted at the Poultry Farming Sector of the Experimental Farm of the Federal University of Mato Grosso, located in the municipality of Santo Antônio do Leverger, MT, under approval from the Ethics Committee for Animal Use (CEUA) of the Federal University of Mato Grosso under protocol No. 23108.194864/2017-37.

A total of 252 laying hens (Novogen Brown) aged 52 weeks and weighing 1.740 ± 0.11 kg, with an initial laying rate of $80.00 \pm 5\%$, were used for 63 days divided into three periods of 21 days each. The experimental design used was completely randomized, with four treatments and seven replications each.

The birds were housed on a floor system in 28 boxes measuring 1.76×1.53 m (length $\times$ width). The boxes were equipped with tubular feeders and pendulum drinkers. Additionally, two nests measuring $0.5 \times 0.25 \times 0.25$ m (length $\times$ width $\times$ height) and a perch 0.40 m above the ground were provided, providing 2.44 m^2 of free space.

With the obtained free space, the densities of 6 birds box^{-1} ($0.406 \text{ m}^2 \text{ bird}^{-1}$), 8 birds box^{-1} ($0.305 \text{ m}^2 \text{ bird}^{-1}$), 10 birds box^{-1} ($0.244 \text{ m}^2 \text{ bird}^{-1}$), and 12 birds box^{-1} ($0.203 \text{ m}^2 \text{ bird}^{-1}$) were calculated, as shown in Table 1.

Table 1. Specifications of the experimental treatments.

Treatment	Density ($\text{m}^2 \text{ hen}^{-1}$)	Number of hens per experimental unit	Number of hens per treatment
T1	0.406	6	42
T2	0.305	8	56
T3	0.244	10	70
T4	0.203	12	84

The experimental diet (Table 2) used was formulated based on corn and soybean meal following the recommendations and nutritional compositions of Rostagno et al. (2017).

Table 2. Ingredients and calculated percentage composition of the experimental diet.

Ingredients	%
Ground corn	65.15
Soybean meal	21.25
Limestone	8.9
Dicalcium phosphate	1.1
Common salt	0.4
Laying hens premix ⁽¹⁾	1.87
L-Lysine HCl	0.06
DL-Methionine	0.24
L-Threonine	0.03
Soybean oil	1.00
Calculated nutritional composition	
Metabolizable energy (kcal kg^{-1})	2.850
Crude protein (%)	14.74
Crude fiber (%)	4.52
Digestible lysine (%)	0.736
Digestible methionine+cystine (%)	0.721
Digestible tryptophan (%)	0.169
Digestible threonine (%)	0.567
Calcium (%)	3.893
Available phosphorus (%)	0.318
Sodium (%)	0.179

⁽¹⁾Composition of the premix: Calcium (min) 80 g kg^{-1} , Calcium (max) 100 g kg^{-1} , Phosphorus (min) 37 g kg^{-1} , Sodium (min) 20 g kg^{-1} , Methionine (min) 21.5 g kg^{-1} , Lysine (min) 18 g kg^{-1} , Vitamin A (min) 125,000 IU kg^{-1} , Vitamin D3 (min) 25,000 IU kg^{-1} , Vitamin E (min) 312 IU kg^{-1} , Vitamin K3 (min) 20 mg kg^{-1} , Vitamin B1 (min) 20 mg kg^{-1} , Vitamin B2 (min) 62.5 mg kg^{-1} , Vitamin B6 (min) 37.5 mg kg^{-1} , Vitamin B12 (min) 200 mcg kg^{-1} , Folic Acid (min) 6.25 mg kg^{-1} , Pantothenic Acid (min) 125 mg kg^{-1} , Biotin (min) 1.25 mg kg^{-1} , Choline (min) 1700 mg kg^{-1} , Niacin (min) 312 mg kg^{-1} , Copper (min) 125 mg kg^{-1} , Iron (min) 680 mg kg^{-1} , Iodine (min) 8.75 mg kg^{-1} , Manganese (min) 937 mg kg^{-1} , Selenium (min) 3.75 mg kg^{-1} , Zinc (min) 500 mg kg^{-1} , Fluorine (max) 370 mg kg^{-1} .

The feed was provided twice a day (at 08:00 and 16:00 hours), and water was provided ad libitum. The temperatures and relative humidity of the air were recorded twice daily (at 08:00 and 15:00 hours) using a digital thermohygrometer. A total of 16 hours of light per day (natural + artificial) was provided, controlled by an automatic timer.

Production performance

At the beginning and end of each production cycle, the birds were evaluated for body weight (kg bird^{-1}) and body weight variation (g bird^{-1}). Throughout the experimental period, mortality was recorded, and viability (%) was determined by the difference between mortality (%) and 100%. The daily feed intake ($\text{g bird}^{-1} \text{ day}^{-1}$) was calculated by subtracting the amount of feed provided minus the leftovers.

The egg mass conversion (kg kg^{-1}) was determined by dividing the average feed intake by the total egg mass. The conversion per dozen eggs (kg dozen^{-1}) was calculated by dividing the total feed consumption by the number of dozens produced.

Eggs were collected and recorded daily to determine the laying rate ($\%\text{bird day}^{-1}$). The percentages of broken, cracked, and abnormal eggs were recorded to determine the percentage of marketable eggs (%), which was calculated as the number of intact eggs relative to the total number of eggs collected divided by 100.

Internal and external egg quality

The evaluation of egg quality was conducted on the last three days of each 21-day experimental period. All intact eggs from each replicate were collected, and three eggs were randomly selected for analysis. The specific gravity of the eggs (g cm^{-3}) was determined by immersing the eggs in saline solutions with densities ranging from 1.060 to 1.095 g cm^{-3} at intervals of 0.005 g cm^{-3} . These solutions were properly calibrated using a densimeter (OM-5565, Incoterm).

The collected eggs were broken, and the weight of the yolk (g) was obtained by manually separating it and weighing it on a precision scale accurate to 0.01 g. Then, the eggshells were washed and air-dried for 72 hours, and the weight of the shells (g) was measured on a precision scale. The weight of the albumen (g) was calculated as the difference between the total egg weight, the shell weight, and the yolk weight.

The percentages of albumen (%), yolk (%), and shell (%) were obtained by dividing the weights of the respective components by the total egg weight, and the result was multiplied by 100. The albumen height (mm) was determined by the average of four measurements taken at distinct points in the equatorial region of the egg using an external micrometer. The yolk diameter was measured with a precision digital caliper accurate to 0.01 mm. The Haugh unit was obtained using the formula $UH = 100 \times \log(H + 7,57 - 1,7 \times PO \times 0,37)$, where H is the albumen height (mm) and PO is the weight of the whole egg (g) according to Eisen et al. (1962).

Physiological parameters

For the collection of physiological variables related to thermoregulation, measurements were taken once a week throughout the experimental period at two times of the day (08:00 and 15:00h) using a sample of 10% of the birds from each experimental plot. Rectal temperature ($^{\circ}\text{C}$) (RT) was measured using a digital clinical thermometer with a rigid tip (iColor- THGTH150B - White - G-Tech®) inserted into the cloaca of the birds, with an audible signal emitted when the temperature stabilized.

Subsequently, physiological data, including head, shin, chest, back, and wing temperatures, were collected using an infrared thermometer (Digital Infrared Thermometer with Laser Pointer (I.R. THERMOMETER - Infrared®)) with a laser pointer 15 cm from the animal's skin.

The surface temperature values were inserted into the formula developed by Dahlke et al. (2005), where the average surface temperature (AST) of the bird is represented by the following formula: $AST = (0.70 \times T.\text{back}) + (0.12 \times T.\text{wing}) + (0.03 \times T.\text{head}) + (0.15 \times T.\text{leg})$. Subsequently, the average body temperature (ABT) of the birds was calculated according to the formula proposed by Richards (1971): $ABT = (0.3 \times AST) + (0.7 \times RT.\text{Com})$

Bird behavior

The assessment of the frequency of analyzed behaviors was conducted through instant monitoring, wherein each bird was individually observed for up to 10 seconds. During the evaluation of each cage and box, the number of birds expressing a particular behavior at that moment was recorded.

Assays were conducted twice a week by the same evaluator at 09:00, 12:00, 15:00, and 18:00 throughout the entire experimental period. Each monitoring session at these times lasted an average of 1 hour and 30 minutes, resulting in a total of 108 hours of observation.

The observed behaviors were adapted from Casey-Trott and Widowski (2016), considering the preliminary selection of the main natural behaviors of birds already subjected to experimental conditions to standardize the natural behavior of birds for subsequent comparisons (Table 3).

Table 3. Ethogram of observed behaviors of laying hens.

Behavior	Description
Idle	The moment when the animal does not perform any action, lying down or sitting, without showing restlessness.
Drinking	Action in which the animal moves to the water source.
Eating	Action in which the animal moves to the food source.
Feather interaction	Animals clean their wings and body using the beak and investigating feathers.
Comfort	Animals showing signs of comfort, stretching legs and wings. Include behaviors such as shaking the body and tail.
Aggressive pecking	Act in which one animal invests aggressively in another with pecking.
Nonaggressive pecking	An animal pecks at another animal in a nonaggressive manner, usually in the head region.
Scratching	Movement around the box without showing restlessness, with the animal scratching the bedding with its feet.
Panting	Action in which the animal demonstrates thermal stress and needs to regulate heat through panting.
Fleeing	Fleeing from another pursuing animal.
Others	Any other behaviors not listed.

The collected data were analyzed for the frequency of behaviors and subjected to the Kruskal–Walli’s test. It is important to highlight that naturally, two or more behaviors can occur simultaneously, which may result in values exceeding 100%. This situation arises due to the possibility of overlapping behaviors analyzed during observations, such as panting behavior, which may occur simultaneously with another type of behavior.

Statistical analysis

The data were previously subjected to tests of residual normality (Shapiro–Wilk), homogeneity of variances (Bartlett), and independence of errors (Durbin–Watson). Subsequently, the results that met the assumptions were subjected to analysis of variance at a 5% probability level using the statistical software R (R Core Team, 2018). To verify the effects ($p < 0.05$) of the treatments, the model described below was adopted, considering results with p values below 0.05.

$$Y_{ik} = \beta_0 + \beta_i + \epsilon_{ik}$$

where:

- Y_{ik} = variable measured in experimental unit k , subjected to housing density i ;
- β_0 = general constant;
- β_i = effect of different housing densities;
- ϵ_{ik} = random error associated with each observation.

The effects of density were estimated through the analysis of variables by linear and quadratic regression models according to the best fit obtained for each variable. Nonparametric variables related to bird behavior were subjected to the Kruskal–Wallis test with Dunn–Bonferroni post hoc correction at the 5% significance level.

Results and discussion

The birds raised in the floor system experienced thermal stress both in the morning and in the afternoon, with temperatures above their comfort zone, which is typically between 18 and 28°C. However, the relative humidity remains within the range required for heat dissipation, between 50 and 70% (Table 4).

The temperature of the facilities must be monitored, as during thermal stress, the physiological and metabolic parameters of the animals are altered, leading to a series of productive losses (Grunitzky et al., 2020). Attia et al. (2020) emphasized that in situations of thermal stress, defense systems generate a compensatory response, leading to energy mobilization and the depletion or diversion of food energy for the maintenance of homeothermy. The productive performance and lower egg quality of birds exposed to high temperatures decrease (Bittencourt et al., 2023).

There was a significant ($p < 0.05$) effect on the variables of feed consumption and laying rate at different densities, showing a decreasing linear behavior, as presented in Table 5.

Table 4. Measures of the central tendency and dispersion of temperature and air humidity (maximum and minimum) were recorded in the production environment throughout the experimental period in the morning and afternoon.

Items	Morning				Afternoon			
	Temperature (°C)		Humidity (%)		Temperature (°C)		Humidity (%)	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
$\bar{x}$	35.4	26.3	69.5	29.6	38.3	27.7	64.3	25.4
s	4.87	1.79	0.13	0.15	2.50	2.50	0.14	0.09
s ²	23.68	3.20	0.02	0.02	6.25	6.27	0.02	0.01
SEM	0.81	0.29	0.02	0.02	0.42	0.42	0.02	0.01
Min	23.0	20.0	44.0	20.0	31.8	23.2	31.0	20.0
Max	42.2	29.1	90.0	84.0	42.4	35.8	91.0	52.0

$\bar{x}$ = mean; s = standard deviation; s² = sample variance; SEM = standard error of the mean; Min = minimum; Max = maximum.

Table 5. Productive performance of laying hens raised on the floor as a function of different housing densities.

Items	Densities (m ² Hen ⁻¹)				SEM	P Value	
	0.406 (n=42)	0.305 (n=56)	0.244 (n=70)	0.203 (n=84)		L	Q
FCR (g ⁻¹ hen ⁻¹ day ⁻¹)	113.1	99.8	98.5	84.7	0.002	<0.001	0.939
BW (kg ⁻¹ hen ⁻¹)	1.73	1.74	1.76	1.72	0.020	0.936	0.528
FCRD (kg ⁻¹ dz ⁻¹)	1.67	1.52	1.63	1.55	0.038	0.304	0.415
FCRM (kg ⁻¹ kg ⁻¹)	2.44	2.58	2.72	2.57	0.070	0.403	0.325
LR (% hen ⁻¹ day ⁻¹)	91.31	80.95	72.99	72.18	2.30	0.001	0.215
ME (%) [†]	99.267	99.294	99.208	99.577	0.124	0.672	
BWV(g hen ⁻¹) [†]	114.28	77.57	57.42	80.01	0.024	0.579	

FCR = feed consumption (g⁻¹ hen⁻¹ day⁻¹); BW = body weight (kg hen⁻¹); FCRD = feed conversion ratio per dozen eggs (kg dozen⁻¹); FCRM = feed conversion ratio per unit mass of eggs (kg kg⁻¹); LR = laying rate (% hen day⁻¹); ME = marketable eggs (%); BWV = body weight variation (g hen⁻¹). L = P value of linear analysis. Q = P value of quadratic analysis; SEM = standard error of the mean. [†]p > 0.05 not significant according to the Kruskal–Wallis test with Dunn–Bonferroni post hoc correction. Equations: FCR ($\gamma = -4.325x + 137.95$; $r^2 = 0.92$), LR ($\gamma = -3.2675x + 108.77$; $r^2 = 0.89$).

The birds with the lowest density (0.203 m² hen⁻¹), which had the highest number of animals (12 hens), showed lower feed consumption, likely associated with competition for access to the feeder and thermal stress. On the other hand, the laying rate exhibited a decreasing trend from higher to lower densities, a factor associated with the low welfare of the animals. Philippe et al. (2020) reported that higher bird density per m² results in lower feed consumption due to social hierarchy factors and feeder access; larger and heavier birds dominate over smaller and lighter birds.

Similar findings were reported by Farinhas et al. (2023), who reported that higher bird density per m² leads to increased stress in these animals due to limited space, competition for feeders, and resting areas, resulting in a decrease in laying rate and lower egg quality.

According to Weimer et al. (2019), recommendations for cage-free production systems suggest a density of approximately 7 to 11 birds per m². The results of this study suggest that the optimal density for laying hens in cage-free systems is 6 birds m⁻² (0.406 m² hen⁻¹), which is an acceptable laying rate (91.31%), and that the optimal density is 8 birds m⁻² (0.305 m² hen⁻¹), which is an acceptable laying rate (80.95%). Above these densities, the laying rate is considered low, potentially resulting in losses.

Although there was no significant effect (p > 0.05) of the different densities on the egg quality parameters, density had no effect on the Haugh unit (HU) values, as presented in Table 6.

Table 6. Egg quality of laying hens raised on the floor as a function of different housing densities.

Items	Densities (m ² hen ⁻¹)				EPM	P-Valor	
	0.406 (n=42)	0.305 (n=56)	0.244 (n=70)	0.203 (n=84)		L	Q
EW (g)	67.09	65.56	66.90	67.17	0.447	0.702	0.333
SG (g cm ⁻³)	1.081	1.080	1.079	1.082	0.001	0.955	0.139
HU	76.17	74.69	73.96	72.90	0.861	0.193	0.905
YW (g)	14.57	14.70	14.73	14.99	0.108	0.200	0.769
SW (g)	6.22	6.04	6.19	6.34	0.600	0.359	1.812
AW (g)	46.29	44.93	45.50	45.93	0.474	0.907	0.371
ST (mm)	0.53	0.52	0.53	0.52	0.002	0.405	0.290
%Y	21.78	22.36	22.19	22.30	0.219	0.499	0.608
%S	9.30	9.27	9.20	9.49	0.076	0.493	0.311
%A	68.83	68.54	68.60	67.74	0.244	0.154	0.570

EW = egg weight (g); SG = specific gravity (g cm⁻³); HU = Haugh unit; YW = yolk weight (g); SW = shell weight (g); AW = albumen weight (g); ST = shell thickness (mm); %Y = % yolk; %S = % shell (mm); %A = % albumen; L = P value of linear analysis; Q = P value of quadratic analysis; SEM = standard error of the mean.

The decreasing trend in HU values may be associated with the thermal stress experienced by the birds during the experimental period, as well as the egg collection time, as high temperatures tend to result in lower egg quality, and the laying quality is affected (Paiva et al., 2019).

Reis et al. (2019) observed the same behavior, where birds subjected to thermal stress produced lower-quality eggs, with a reduction in albumen height and lower Haugh unit values. The density of birds m^{-2} is closely related to egg quality; the more factors that contribute to animal stress, the greater the effect on egg quality (Aguilar et al., 2021). Sokolowicz et al. (2018) emphasize that the type of housing system is a major influencer of egg quality. In their study, eggs from the floor-raising system exhibited lower Haugh unit values and lower albumen heights. Vlckova et al. (2019) highlighted two factors that can directly influence egg quality: increased age, which is correlated with increased egg size, and egg exposure in environments with relatively high ammonia concentrations, as observed in alternative systems.

There was a significant difference ($p < 0.05$) in the rectal temperature, mean body temperature, and mean surface temperature in the afternoon (Table 7).

Table 7. Physiological parameters of laying hens raised on the floor as a function of different housing densities.

Parameters	Densities (m ² hen ⁻¹)				SEM	P Value	
	0.406 (n=42)	0.305 (n=56)	0.244 (n=70)	0.203 (n=84)		L	Q
Morning period							
RT (°C)	40.96	41.07	41.07	40.99	0.480	0.850	0.349
MST (°C)	34.61	33.69	34.79	34.22	0.222	0.973	0.701
MCT (°C)	38.99	38.87	39.19	38.96	0.856	0.774	0.754
Afternoon period							
RT (°C)	41.68	41.71	41.78	41.85	0.041	0.017	0.642
MST (°C)	36.61	36.67	36.77	37.01	0.539	0.005	0.352
MCT (°C)	40.09	40.20	40.28	40.40	0.036	0.001	0.973

RT = Rectal temperature; MST = mean surface temperature; MCT = mean body temperature; L = P value of linear analysis; Q = P value of quadratic analysis; SEM = standard error of the mean.

The effects of increasing rectal temperature (TR), mean surface temperature (TMS) and mean body temperature (TMC) can be explained as reported by Kim et al. (2021). In situations of exposure to high temperatures, animals immediately implement mechanisms to maintain thermoregulation and homeostasis, including vasodilation, radiation, and convection. In situations where animals face the challenge of high temperatures, increases in rectal temperature and body surface temperature are observed, which are essential underlying mechanisms of thermoregulation (Nawab et al., 2020).

The same effect was highlighted by Andrade et al. (2018), who reported that laying hens exposed to temperatures outside their comfort zone respond physiologically to maintain body temperature, which is usually characterized by an increase in rectal and body surface temperature, indicating thermal stress.

There was no significant effect ($p > 0.05$) for the variables of bird behavior frequency subjected to different densities, as shown in Table 8.

Table 8. Behavior frequency of laying hens raised on the floor as a function of housing density.

Behavior Frequency (%)	Densities ($m^2 \text{ hen}^{-1}$)				SEM (%)	P value
	0.406 (n=42)	0.305 (n=56)	0.244 (n=70)	0.203 (n=84)		
Idle	11.38	9.09	12.86	10.85	0.473	0.052
Eating	18.29	16.46	15.95	14.91	0.676	0.382
Drinking	10.46	10.09	10.82	10.12	0.500	0.866
Feather pecking	3.65	4.00	3.69	3.63	0.177	0.913
Comfort	17.41	15.46	15.10	13.53	0.614	0.245
Aggressive pecking	1.19	0.98	2.44	1.38	0.378	0.735
Nonaggressive pecking	1.57	2.19	2.04	2.69	0.169	0.118
Scratching	12.29	10.82	9.86	10.61	0.898	0.766
Panting	21.40	20.15	19.00	20.19	0.524	0.274
Fleeing	0.28	0.24	0.47	0.44	0.098	0.620
Other	5.40	7.67	7.91	9.39	0.538	0.176

SEM = standard error of the mean; $p < 0.05$, significant according to the Kruskal–Wallis test with Dunn–Bonferroni post hoc correction.

Behavioral assessment of birds is one of the mechanisms used to evaluate an individual's relationship with the environment in which it is placed (Kang et al., 2018). Increased density did not directly affect the animals' behavioral frequency, but it is possible to observe that the greater the density of animals per m² is, the lower their behavioral frequency.

High densities of laying hens per m² can predispose them to welfare problems, compromising performance and egg quality. It is recommended to work with an adequate number of animals for a given shed area, allowing the animals to have ideal conditions for the manifestation of their genetic potential and to be satisfied with the environment in which they are placed.

Conclusion

Recommendations for cage-free poultry farming systems recommend densities of 6 hens box⁻¹ (0.406 m² hen⁻¹) to 8 hens box⁻¹ (0.305 m² hen⁻¹), without density affecting performance, egg quality, physiological parameters, or animal behavior.

Data availability

Not available.

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