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Live Performance, Carcass Yield, and Welfare of Broilers of Different Genetic Strains Reared at Different Housing Densities

■Author(s)

Arruda JNT[I]
Mendes AS[I]
Guirro ECBP[II]
Schneider M[II]
Sikorski RR[I]
Sausen L[I]
Dias ER[I]
Bonamigo DV[I]

[I] Department of Animal Science. Technological Federal University of Paraná, Dois Vizinhos, PR, Brazil.
[II] Department of Veterinary Medicine. Federal University of Paraná/UFPR. Palotina. PR. Brazil.

■Mail Address

Corresponding author e-mail address
Angélica Signor Mendes
UTFPR - Estrada para Boa Esperança, km 04, CXp 157 – 85660-000 – Dois Vizinhos/PR/Brasil
Phone: (46) 3536 8405
Email: angel.concordia@hotmail.com

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ABSTRACT

This study evaluated the performance, carcass yield and quality, and physiological stress indicators of broilers of three genetic strains reared at three housing densities for 29 days. A total of 828 day-old male chicks, with average initial weight of 40.0± 2.0g were used. Three genetic strains (Cobb 500, Ross 808, and Ross 508, with 276 birds each) and three housing densities (17, 19, and 21 broilers/m²) were tested. A completely randomized experimental design in a 3 x 3 factorial arrangement, with four replicates of 23 birds each, was applied. The following responses were evaluated: performance parameters (average weekly body weight, average daily gain, feed intake, feed conversion ratio), physiological stress indicators (blood glucose levels, blood cell counts), and carcass yield and quality (dermatosis, bruising, dermatitis, and femoral degeneration scores). Average weekly body weight (BW) and daily weight gain (DWG) were not influenced by rearing density ($p \geq 0.05$), but Cobb 500 broilers were the heaviest during the analyzed period. In the second week, Ross 508 birds showed better feed conversion ratio (FCR) when housed at the density of 17 broilers/m² ($p \leq 0.001$), whereas the best FCR of Ross 808 and Cobb 500 broilers was obtained at 21 broilers/m² ($p \leq 0.001$). Carcass yield was not influenced by the treatments ($p \geq 0.05$). Physiological stress indicators were not affected by the treatments, and remained within normal ranges ($p \geq 0.05$). Dermatosis scores (scratches) increased ($p \leq 0.05$) when housing density increased from 17 to 19 broilers /m².

INTRODUCTION

Poultry production is the fastest growing sector of the animal production industry. Brazilian chicken meat production reached 13.058 million tons in 2011, which represents a 6.8% increase relative to 2010. These figures make of Brazil the third global chicken meat producer, coming after China, which produced 13.2 million tons in 2011, and the USA, with 16.757 million tons (UBA, 2012).

This impressive growth is the result of developments in nutrition, genetics, health, and facilities. In addition, new management systems, aiming at obtaining the greatest productivity in the shortest possible time, such using high broiler housing density, have been proposed. High housing density may impair broiler performance as a result of worse air quality in the house, increased ammonia production and volatilization, and reduced feeder and drinker space. This results in reduced growth rate, worse feed efficiency, and often, carcass downgrade. Other consequences are increased mortality, high incidence of diseases associated with poor air quality, and poor immunity (Perdomo, 2001). In addition, new commercial broiler strains have been developed, and their response to high-density rearing conditions still needs to be evaluated.

The effect of housing density on broiler live performance has been extensively studied, as well as on the welfare of broilers (Estevez, 2007), particularly on their physiological responses to the stress caused by high rearing density. Animals under stress may present both behavioral and physiological changes. The latter include increased serum levels of proteins and glucose, and changes in the number of immune cells, particularly in the heterophil: lymphocyte ratio.

High housing densities are sometimes associated with increased density of contact dermatitis, and consequent carcass downgrading. In the last few years, changes in consumers' preferences have been observed. Relative to chicken meat, there is a higher demand for deboned parts and products, as well as for ready-to-cook products, possibly due to a greater participation of women in the labor market (Castillo, 2001). Moreover, consumer markets are becoming more demanding in terms of chicken meat quality. Arab countries are the main exporting market of many Brazilian poultry companies, that sell mostly small whole chickens, the so-called "grillers". Such market demands high carcass quality.

Therefore, the objective of this study was to evaluate the effects of stress induced by high rearing density on the live performance, physiological stress indicators, and carcass yield and quality of griller chickens belonging to three different genetic strains.

MATERIALS AND METHODS

The experiment was carried out at the experimental poultry house of the Poultry Innovation Lab (Laboratório de Inovações Avícolas – LINAV) of the Federal Technological University of Paraná, Dois Vizinhos, PR, Brazil. The lab is located at 250º 45' 00" South latitude, 53º 03' 25" West longitude, and 509 m altitude. The climate is subtropical Cfa. The study was carried out between August and September of 2012 for a total of 29 days. Birds were handled according to the norms of the Committee of Ethics and Animal Research of that university, established according to the determinations of the Brazilian College of Animal Experimentation (COBEA).

Birds, facilities, and diets

In total, 828 day-old male chicks (276 Ross 808, 276 Ross 508, and 276 Cobb 500 chicks), with initial average weight of 40.0±2.0g, were used. At the hatchery, chicks were selected, weighed, and vaccinated against Marek's disease, fowl pox, and infectious bronchitis.

Birds were housed in an experimental poultry house (25m long x 6m wide) divided in 1.0m x 1.2m pens, each equipped with a trough feeder and four nipple drinkers. The house is equipped with an automatic-heating brooder, and the sides are closed with yellow curtains. The concrete floor was covered with wood shavings (*Pinus taeda* L.). During the experiment, house temperature was maintained within the thermal comfort range.

Water and feed were offered *ad libitum*. The diets were based on corn and soybean meal and formulated to supply the birds' nutritional requirements as recommended Rostagno *et al.* (2005) for the following phases: pre-starter (1-5 days of age), starter (6-14 days), grower (15-23 days), and finisher (24-29 days). The diets included coccidiostats and growth promoters (nicarbazin, narasin, and enramycin in the pre-starter and starter diets; salinomycin and enramycin in the grower diet), except for the finisher diet, which did not contain any coccidiostats or antibiotic growth promoters.

Experimental design

A completely randomized experimental design in a 3 x 3 factorial arrangement (three genetic strains and three rearing densities) was applied, with nine treatments of four replicates, totaling 36 experimental units (pens). The following treatments were evaluated: T1= Ross 808 broilers reared at 17 birds/m², T2= Ross 808 broilers reared at 19 birds/m², T3= Ross 808 broilers reared at 21 birds/m², T4=Cobb 500 broilers reared at 17 birds/m², T5= Cobb 500 broilers reared at 19 birds/m², T6= Cobb 500 broilers reared at 21 birds/m², T7= Ross 508 broilers reared at 17 birds/m², T8= Ross 508 broilers reared at 19 birds/m², and T9= Ross 508 broilers reared at 21 birds/m².

Live performance parameters

By the end of each experimental week, all birds and feed residues were weighed to determine the following live performance parameters: average feed intake (FI), average body weight (BW), daily weight gain (DWG), and feed conversion ratio (FCR). Birds of each of the three evaluated genetic strain were housed in an additional pen per strain for replacement purposes.

Physiological stress indicators

Blood glucose levels and total blood cell counts were used as measures of bird welfare.

- Blood glucose levels

Blood glucose levels were evaluated when birds were 21 and 28 days of age. Three birds per pen were randomly selected and duly identified for blood

collection. Two mL of blood per bird were collected after one hour of fasting in the morning from the brachial vein, using 10-mL syringes and 0.8 x 25 hypodermic needles. Blood was collected in less than 30 seconds. Blood was then stored in tubes containing fluoride, which function is to inhibit clotting and glycolysis. Blood tubes were stored in a cooler at 4-8 ºC, and then submitted to the Clinical Pathology Lab of the Federal University of Paraná, Palotina campus, PR, Brazil. Blood glucose was measured using a commercial kit (Kit Glicose Pap Liquiform, Labtest®, Brazil) in a semi-automatic biochemical analyzer (Quick Lab 2, Drake, Brazil).

- Total blood cell count

In the morning of days 21 and 28, after one hour of feed fasting, three birds per pen were randomly selected for blood collection. Two mL of blood were collected per bird from the brachial vein, using 10-mL syringes and 0.8 x 25 hypodermic needles. Blood was collected in less than 30 seconds. After collection, blood was stored in tubes containing an anti-clotting agent (EDTA). Blood tubes were stored in a cooler at 4-8 ºC, and then submitted to the laboratory mentioned above. Total blood red and white cells were manually counted in a Neubauer chamber according to Natt & Herrick (1952) at 1/200 dilution. The correction factors for leukocytes and erythrocytes were the number of counted cells multiplied by 50 and 10,000, respectively. Packed cell volume was determined using the micro-hematocrit technique; total blood protein by the refractometry method; and hemoglobin levels by the cyano-metahemoglobin method. Wintrobe's indices, including mean cell volume (MCV), mean corpuscular hemoglobin concentration (MCHC), and mean corpuscular volume (MCV), were determined according to Jain (1993) and Pierson (2000) using standardized formulas.

Differential leukocyte counts were performed on blood smear slides stained with hematoxylin-eosin hematological stain (rapid panoptic LB). Heterophils, lymphocytes, eosinophils, monocytes, and basophils were counted, and the heterophil to lymphocyte ratio (H:L) was calculated.

Carcass yield and quality

On day 29, after eight hours of fasting, five birds per pen were randomly selected, identified, weighed to determine final body weight, and transported to a commercial processing plant to be slaughtered. Carcass yield was calculated as carcass weight relative to final body weight. Carcass quality was determined as a function of the presence or absence of dermatitis (breast blisters), dermatoses (scratches), arthritis, and bruising. Femoral degeneration was scored (0-2 scale) by the visual evaluation of the proximal epiphysis of the femur of both legs, according to the method described by Almeida Paz (2008).

Statistical analysis

The obtained data were submitted to analysis of variance (ANOVA) using Assistat (2000) statistical package and means were compared by the test of Tukey at 5% and 1% probability level.

RESULTS AND DISCUSSION

Live performance

Table 1 shows the average live weight of the broilers submitted to the different treatments. There was no interaction between genetic strains and densities ($p \geq 0.05$). Strain differences were observed during all evaluated experimental phases ($p \leq 0.001$), with Cobb 500 broilers presenting heavier weight during the entire experimental period. Despite the lack of statistical significance, there was a slight numerical reduction in live weight as density increased.

Daily weight gain (DWG) results are shown in Table 2. There was no interaction between the evaluated factors ($p \geq 0.05$). However, there were significant differences among the genetic strains in weeks 1 (≤ 0.001), 2 (≤ 0.001), and 4 (≤ 0.05). In week 1 and 2, Cobb 500 broilers presented significantly higher DWG than both Ross 808 and 508, whereas in week 4, Cobb 500 and Ross 808 had higher DWG than Ross 508. Rearing density had no effect on weight gain. Moreira *et al.* (2004) obtained higher DWG in broilers housed at higher densities, but other studies reported no effect (Ravindran *et al.*, 2006) or negative effects (Dozier *et al.*, 2005a) on increasing rearing densities.

The final body weight results of the present experiment are consistent with those obtained by Dozier *et al.* (2005b), who did not find live weight differences in 32-d-old broilers reared in environmentally-controlled houses at densities of 9, 11, 12, or 13 birds/m^2. In addition, Oliveira *et al.* (2005) and Buijs *et al.* (2009) did not observe any effect of rearing density on that parameter either. On the other hand, Moreira *et al.* (2004), evaluating three housing densities (10, 13, or 16 broilers/m^2), observed significant reduction in weight gain in birds housed at 10 and 16 birds/m^2. Mortari *et al.* (2002) also reported reduced body weight as rearing density increased, and Thomas *et al.* (2004), Dozier *et al.* (2005a), and Zuowei *et al.* (2011)

Table 1 – Mean and standard deviation (SD) of the body weight (g), measured at 7, 14, 21 and 28 days of age of broilers, of different strains reared at different densities.

Period (day)	Strains	Density (birds/m²)			Mean	p-value
		17	19	21		
7	ROSS 808	142.86±7.53	142.94±7.40	139.00±1.15	141.60±5.87 b	<0.001*
	COBB 500	154.17±2.28	151.09±7.21	150.00±5.89	151.75±5.33 a	
	ROSS 508	144.65±7.11	140.76±3.71	144.50±4.43	143.30±5.15 b	
	Mean	147.23±7.58	144.93±7.38	144.50±6.10		
	p-value			>0.05ns		>0.05ns
14	ROSS 808	404.17±16.99	398.91±12.10	388.50±8.70	397.19±13.62 b	<0.001*
	COBB 500	429.17±9.20	423.37±24.30	418.00±10.71	423.51±15.43 a	
	ROSS 508	404.76±5.83	397.82±18.01	400.50±10.75	401.03±11.76 b	
	Mean	412.70±16.07	406.70±21.00	402.33±15.60		
	p-value			>0.05ns		>0.05ns
21	ROSS 808	876.43±17.76	864.74±40.68	854.96±40.89	865.38±32.83 b	<0.001*
	COBB 500	903.09±33.62	923.86±11.99	915.81±26.18	914.25±24.78 a	
	ROSS 508	879.80±17.47	855.71±33.60	867.50±34.27	867.67±28.58 b	
	Mean	886.44±25.12	881.44±42.37	879.42±41.40		
	p-value			>0.05ns		>0.05ns
28	ROSS 808	1480.15±20,87	1501.36±38.34	1467.61±29.47	1483.04±31.11 b	<0.001*
	COBB 500	1540.92±26.34	1533.58±13.72	1523.52±14.82	1532.67±18.87 a	
	ROSS 508	1459.13±59.64	1429.22±26.36	1457.31±56.35	1448.55±47.22 b	
	Mean	1493.4050.89±	1488.05±52.14	1482.81±45.67		
	p-value			>0.05ns		>0.05ns

*significant at 5%; **significant at 1%; means followed by different lowercase letters within a column are statistically different; means followed by different uppercase letters within a row are statistically different.

ns= not significant by ANOVA (p≥0.05).

Table 2 – Mean and standard deviation (SD) of the daily weight gain (g/d), measured at 7, 14, 21 and 28 days of age, of broilers of different strains reared at different densities.

Period (day)	Strains	Density (birds/m²)			Mean	p-value
		17	19	21		
7	ROSS 808	14.69±1.07	14.71±1.07	14.14±0.16	14.51±0.84b	
	COBB 500	16.31±0.33	15.87±1.03	15.71±0.84	15.96±0.76a	<0.001**
	ROSS 508	14.95±1.02	14.39±0.53	14.93±0.63	14.76±0.73b	
	Mean	15.32±1.08	14.99±1.05	14.93±0.87		
	p-value			>0.05ns		>0.05ns
14	ROSS 808	37.33±1.36	36.57±0.93	35.64±1.15	36.51±1.28b	
	COBB 500	39.33±1.26	38.89±2.57	38.29±0.81	38.84±1.61a	<0.001**
	ROSS 508	37.16±0.33	36.72±2.13	36.57±1.02	36.82±1.27b	
	Mean	37.94±1.41	37.39±2.12	36.83±1.46		
	p-value			0.1954ns		>0.05ns
21	ROSS 808	67.47±2.12	66.55±6.96	66.64±5.22	66.89±4.70	
	COBB 500	67.70±6.08	71.50±2.00	71.12±2.22	70.11±3.96	0.0878ns
	ROSS 508	67.86±1.97	65.41±2.81	66.71±3.54	66.66±2.78	
	Mean	67.68±3.52	67.82±4.91	68.16±4.12		
	p-value			>0.05ns		>0.05ns
28	ROSS 808	86.25±4.52	90.95±8.17	87.52±3.45	88.24±5.60a	
	COBB 500	91.12±7.23	87.10±1.72	86.81±3.88	88.34±4.83a	0.040*
	ROSS 508	82.76±8.07	81.93±5.45	84.26±3.88	82.98±3.69b	
	Mean	86.71±7.10	86.66±6.48	86.20±3.69		
	p-value			>0.05ns		>0.05ns

*significant at 5%; **significant at 1%; means followed by different lowercase letters within a column are statistically different; means followed by different uppercase letters within a row are statistically different.

ns= not significant by by ANOVA (p≥0.05).

observed that weight gain was reduced when broilers were reared at high densities.

Relative to genetic strains, the live weight results of the present study are consistent with those reported by Moreira *et al.* (2004), who found differences among the three genetic strains (Ross 308, Cobb 500, and Hybro PG) evaluated.

Some of the above-mentioned authors reported other factors that may negatively affect broiler weight gain as rearing density increases, such as environmental temperature, air quality, and feeder and drinker space, were well controlled in the present study, and therefore, did not influence the results.

A significant effect of the interaction ($p \leq 0.001$) between housing density and genetic strain was also observed on feed conversion ratio (FCR) in week 2, as shown in Table 3. When housed at 19 birds/m^2, Ross 508 broilers presented better FCR than the other two strains, whereas at 21 birds/m^2, Cobb 500 and Ross 808 presented the best results ($p \leq 0.001$).

Similar results were reported by Dozier *et al.* (2005a) and Onbasilar (2008), who observed FCR improvement as housing density increased in young broilers. It should be noted that, despite of the lack of statistical significance ($p \geq 0.05$), the best FCR and the lowest FI at the lowest density were obtained only during the period of 21-28 days of age. The evaluated strains presented similar FCR and FI values ($p \geq 0.05$) in weeks 1, 3, and 4, although Cobb 500 broilers were 30g more efficient in the last week than Ross 808, and at 21 birds/m^2, Ross 808 presented the best FCR.

Broilers reared at high densities may present reduced FI, and consequently, worse FCR, due to lack of access to the feeders (Febrer *et al.*, 2006). However, the results of the present study indicate that the number of birds per feeder was not a limiting factor, in agreement with Collins & Sumpter (2007), who reported that broilers group at feeders independently of housing density.

Overall, the performance results were not dramatically affected by the rearing densities evaluated. This is agreement with Jones *et al.* (2005), who found few effects of housing density on the health and welfare of commercial broilers, and no effect on their performance. The results show that the health and well-being are largely determined in the quality of the rearing environment provided by the producer (Febrer *et al.*, 2006). Therefore, the obtained results should not be interpreted as the lack of effect of housing

Table 3 – Mean and standard deviation (SD) of the feed conversion ratio (g/g), measured at 7, 14, 21 and 28 days of age, of broilers of different strains reared at different densities.

Period (day)	Strains	Density (birds/m²)			Mean	p-value
		17	19	21		
7	ROSS 808	1.30±0.02	1.26±0.03	1.29±0.07	1.28±0.05	
	COBB 500	1.35±0.09	1.32±0.12	1.26±0.11	1.31±0.11	>0.05ns
	ROSS 508	1.290.06±	1.27±0.10	1.28±0.08	1.28±0.08	
	Mean	1.31±0.06	1.28±0.09	1.28±0.08		
	p-value		>0.05ns			>0.05ns
14	ROSS 808	1.30±0.02aA	1.31±0.02aA	1.19±0.04aB	1.27±0.06	
	COBB 500	1.33±0.04aA	1.28±0.05aA	1.21±0.03aB	1.27±0.06	0.2714ns
	ROSS 508	1.30±0.03aA	1.21±0.05bB	1.24±0.01aB	1.25±0.05	
	Mean	1.31±0.03a	1.27±0.06b	1.21±0.04c		
	p-value		<0.001**			0.0016**
21	ROSS 808	1.28±0.03	1.38±0.13	1.30±0.05	1.32±0.08	
	COBB 500	1.36±0.11	1.32±0.04	1.29±0.03	1.32±0.07	>0.05ns
	ROSS 508	1.34±0.08	1.34±0.09	1.31±0.04	1.33±0.07	
	Mean	1.33±0.08	1.35±0.09	1.30±0.03		
	p-value		0.3167ns			>0.05ns
28	ROSS 808	1.53±0.09	1.49±0.06	1.52±0.12	1.51±0.08	
	COBB 500	1.44±0.07	1.46±0.08	1.54±0.08	1.48±0.08	0.3217ns
	ROSS 508	1.51±0.07	1.50±0.06	1.58±0.04	1.53±0.07	
	Mean	1.49±0.08	1.48±0.06	1.55±0.08		
	p-value		0.1376ns			>0.05ns

*significant at 5%; **significant at 1%; means followed by different lowercase letters within a column are statistically different; means followed by different uppercase letters within a row are statistically different

ns= not significant by ANOVA ($p \geq 0.05$).

density on broiler welfare; rather, they suggest that merely reducing density without taking into account the environment, is not sufficient to provide good broiler welfare (Oliveira *et al.*, 2004).

Physiological stress indicators

The physiological stress indicators of the different strains of broilers reared at different densities are presented in Tables 4, 5 and 6. Blood glucose levels at 21 days of age were significantly reduced as housing density increased ($p \leq 0.05$), but were not affected by rearing density in the other evaluated periods ($p \geq 0.05$). According to Bonamigo *et al.* (2011), high blood glucose levels indicate acute stress, as glucose needs to be readily available to the sympathetic nervous system to be utilized when animals are submitted to adverse situations. Lin *et al.* (2004) also claim that blood glucose level is an excellent indicator of stress in poultry. Thaxton *et al.* (2006) did not find any effect of rearing density on blood glucose, corticosterone, or cholesterol levels in broilers reared at 20 kg/m² and 55 kg/m². Zuowei *et al.* (2011), did not observe any statistical effect, despite a slight increasing trend of increasing blood glucose levels as rearing density increased.

The results of the present study, therefore, show that increasing the rearing density from 17 to 21 birds/m² did not affect the broilers' welfare, as the evaluated physiological stress indicators did not increase as density increased.

Packed cell volume and total blood protein levels were not influenced ($p \geq 0.05$) by the treatments. These

Table 4 – Average blood glucose, hematocrit, and total blood protein values, measured at 21 and 28 days of age, of broilers of different strains reared at different densities.

Parameters	Strains	Density (birds/m²)			Average	p-value
		17	19	21		
Glucose (mg/dL) 21days	ROSS 808	246.17	205.25	199.00	216.81	
	COBB 500	226.67	221.17	216.75	221.53	0.1297ns
	ROSS 508	206.83	207.25	205.08	206.39	
	Mean	226.56 a	211.22 ab	206.94 b		
	p-value			0.0349*		0.0969ns
Glucose (mg/dL) 28 days	ROSS 808	231.42	240.00	233.00	234.81	
	COBB 500	232.00	235.30	230.50	232.60	>0.05ns
	ROSS 508	232.42	225.67	226.67	228.25	
	Mean	231.95	233.66	230.06		
	p-value			>0.05ns		>0.05ns
Hematocrit (%) 21 days	ROSS 808	26.08	26.83	26.50	26.47	
	COBB 500	25.83	25.00	24.92	25.25	0.1297
	ROSS 508	24.25	25.19	25.50	24.98	
	Mean	25.39	25.67	25.64		
	p-value			>0.05ns		>0.05ns
Hematocrit (%) 28 days	ROSS 808	32.25	32.42	32.17	32.28	
	COBB 500	32.83	34.75	24.58	30.72	0.3487
	ROSS 508	33.75	32.50	32.17	32.81	
	Mean	32.94	33.22	29.64		
	p-value			>0.05ns		>0.05ns
Proteins (g/dL) 21 days	ROSS 808	3.90	3.97	4.13	4.00 b	
	COBB 500	3.92	3.93	4.02	3.96 b	0.0126*
	ROSS 508	4.20	4.23	4.13	4.19 a	
	Mean	4.01	4.04	4.09		
	p-value			>0.05ns		>0.05ns
Proteins (g/dL) 28 days	ROSS 808	4.45	4.47	4.17	4.36	
	COBB 500	4.13	4.32	4.27	4.24	0.1193ns
	ROSS 508	4.45	4.35	4.48	4.43	
	Mean	4.34	4.38	4.31		
	p-value			>0.05ns		0.2011ns

*significant at 5%; **significant at 1%; colums:small letters; lines:capital letters

ns= not significant by ANOVA ($p \geq 0.05$).

Table 5 – Mean hemoglobin values and leukocyte and lymphocyte counts, measured at 21 and 28 days of age, of broilers of different strains reared at different densities.

Parameters	Strains	Density (birds/m²)			Mean	p-value
		17	19	21		
Hemoglobin (g/dL) 21days	ROSS 808	38.93	37.33	37.44	37.90	
	COBB 500	40.27	33.55	41.63	38.48	>0.05ns
	ROSS 508	37.08	35.88	36.05	36.34	
	Mean	38.76	35.59	38.37		
	p-value			0.2730ns		>0.05ns
Hemoglobin (g/dL) 28 days	ROSS 808	36.67	39.32	40.10	38.70	
	COBB 500	42.12	41.90	38.83	40.95	>0.05ns
	ROSS 508	38.68	41.34	35.66	38.56	
	Mean	39.16	40.85	38.20		
	p-value			>0.05ns		>0.05ns
Leucocytes (/µL) 21 days	ROSS 808	14841.67	14212.50	13575.00	14209.72	
	COBB 500	13641.67	14333.33	15829.17	14601.39	>0.05ns
	ROSS 508	17020.83	16436.11	13037.50	15498.15	
	Mean	15168.06	14993.98	14147.22		
	p-value			>0.05ns		0.3824ns
Leucocytes (/µL) 28 days	ROSS 808	25550.00	15804.17	15445.83	18933.33	
	COBB 500	13766.67	25745.83	17366.67	18959.72	>0.05ns
	ROSS 508	27662.50	20293.67	19533.33	22496.50	
	Mean	22326.39	20614.56	17448.61		
	p-value			>0.05ns		0.2315
Lymphocytes (%) 21 days	ROSS 808	78.83	68.58	66.17	71.19 b	
	COBB 500	67.83	69.50	72.58	69.97ab	0.0329*
	ROSS 508	74.58	75.67	85.42	78.56 a	
	Mean	73.75	71.25	74.72		
	p-value			>0.05ns		0.3943
Lymphocytes (%) 28 days	ROSS 808	80.42	81.17	81.92	81.17 b	
	COBB 500	79.17	83.75	81.00	81.31 a	0.0338*
	ROSS 508	83.42	79.91	82.83	82.05 ab	
	Mean	81.00	81.61	81.92		
	p-value			>0.05ns		>0.05ns

*significant at 5%; **significant at 1%; colums: small letters; means followed by different uppercase letters within a row are statistically different

ns= not significant by ANOVA (p≥0.05).

results are consistent with the findings of Bonamigo *et al.* (2011), who did not find any effect of rearing density on these parameters.

According to Bounous & Stedman (2000), leukocyte and lymphocyte counts normally range between 12,000-30,000 cells/µL and 7,000-17,500 cells/µL, respectively, and a 50% or higher ratio of lymphocytes relative to total leukocytes is considered physiologically normal (Tabeli *et al.*, 2005). Therefore, there was no influence of the treatments on the broilers' immune system because the number of leukocytes is within the normal range for broilers, and the percentage of lymphocytes relative to total leukocytes was higher than 60% (Table 5). Other leukocyte counts were not influenced by the treatments (p≥0.05).

Table 6 shows the obtained heterophil percentages and heterophil to lymphocyte ratios (H:L). There was no effect of rearing density on these parameters in none of the evaluated ages (p≥0.05). However, H:L ratio was affected by genetic strain on day 21, when Ross 808 broilers presented significantly lower H:L ratio compared with the two other genetic strains. Nevertheless, it should be noted that the calculated H:L ratios were within the range considered normal for all treatments, which is 1:2. Higher blood H:L ratios are considered indicators of stress in poultry, as a result of ACTH release, reducing the number of circulating lymphocytes (Macari, 2002).

The absence of changes in H:L ratios in the present study indicates that birds did not suffer any physiological stress as a result of the rearing densities applied, and therefore, that their physiological welfare was maintained. These results are consistent with those of Heckert *et al.* (2002), who did not detect any

Table 6 – Mean heterophil counts and heterophil to lymphocyte ratios, measured at 21 and 28 days of age, of broilers of different strains reared at different densities.

Parameters	Strains	Density (birds/m²)			Average	p-value
		17	19	21		
Heterophils (%) 21days	ROSS 808	18.83	21.50	26.67	22.33 a	
	COBB 500	22.83	22.75	19.58	21.72 ab	0.0328*
	ROSS 508	15.92	19.00	10.58	15.17 b	
	Mean	19.19	21.08	18.94		
	p-value			>0.05ns		
Heterophils (%) 28 days	ROSS 808	13.33	13.92	13.17	13.47	
	COBB 500	15.75	12.25	13.83	13.94	>0.05ns
	ROSS 508	12.67	16.58	12.67	13.97	
	Mean	13.92	14.25	13.22		
	p-value			>0.05ns		>0.05ns
H/L ratio 21 days	ROSS 808	0.34	0.46	0.66	0.49 a	
	COBB 500	0.60	0.53	0.37	0.50 a	0.0336*
	ROSS 508	0.31	0.27	0.13	0.24 b	
	Average	0.42	0.42	0.39		
	p-value			>0.05ns		0.3635ns
H/L ratio 28 days	ROSS 808	0.17	0.18	0.19	0.18	
	COBB 500	0.24	0.15	0.19	0.19	>0.05ns
	ROSS 508	0.16	0.27	0.16	0.20	
	Average	0.19	0.20	0.18		
	p-value			>0.05ns		>0.05ns

*significant at 5%; **significant at 1%; colums: small letters; means followed by different uppercase letters within a row are statistically different.

ns= not significant by ANOVA (p≥0.05).

differences in H:L ratios or in the humoral immune response of broilers reared at different densities. Thaxton *et al.* (2006) did not find any H:L ratio differences between broilers reared at densities of 20 kg/m² or at 55 kg/m² either. On the other hand, Bonamigo *et al.* (2011), despite not detecting any significant influence of housing density on the H:L ratio of broilers, obtained H:L ratios higher than 1.0 in birds housed at 10 and 15 birds/m², and concluded that these birds were under stress.

Carcass yield

Table 7 shows the carcass yield results of 29-d-old broilers of different genetic strains reared at different densities. The results in Table 7 show that there was no effect of rearing density or genetic strain on the carcass yield (p≥0.05). These results are consistent with those of Oliveira *et al.* (2004), who did not find any effect of rearing density on carcass and parts yield, and with Fernandes *et al.* (2001), who obtained similar carcass yield in broilers of different genetic strains. The results suggest that increasing housing density from 17 to 21 birds/m² was not sufficient to cause carcass yield reduction in none of the three evaluated strains as a consequence of competition or stress caused by overcrowding.

Carcass quality

Dermatosis, bruising, dermatitis, arthritis, and femoral degeneration scores are shown in Table 8.

Table 7 – Mean and standard deviation (SD) of the carcass yield (%) of 29-d-old broilers of different strains reared at different densities.

Parameters	Strains	Density (birds/m²)			Average	p-value
		17	19	21		
Carcass (%)	ROSS 808	72.91±2.66	70.32±8.61	68.24±7.06	70.49±6.30	
	COBB 500	68.08±7.84	71.01±1.32	70.89±0.27	69.99±4.39	>0.05ns
	ROSS 508	69.97±1.19	66.57±6.20	72.08±1.48	69.54±4.13	
	Mean	70.32±4.84	69.30±5.95	70.40±4.12		
	p-value			>0.05ns		0.3646

*significant at 5%; **significant at 1%; means followed by different lowercase letters within a column are statistically different; means followed by different uppercase letters within a row are statistically different.

ns= not significant by ANOVA (p≥0.05).

Out of the evaluated carcass quality parameters, only dermatosis scores were influenced by rearing density ($p \leq 0.05$). In addition, those scores were affected by the interaction between genetic strain and rearing density ($p \leq 0.05$).

Dermatosis scores increased as rearing density increased ($p \leq 0.05$) from 17 to 19 birds/m^2, but only a numerical difference was observed between the densities of 17 and 21 birds/m^2. Except for Ross 508, the dermatosis scores of the other two genetic strains increased with increasing rearing density.

These results are in agreement with the findings of Hall (2001), who observed the incidence of scratches (dermatosis) in broiler carcasses increased from 0.250 to 0.517% when the rearing density increased from 34 to 40 kg/m^2. Arnould & Faure (2003) also reported that high rearing densities not only has negative effects on live performance, but also increases the incidences of lesions such as bruising, scratches, and footpad dermatitis. The observed increase in dermatosis score may be attributed to the reduction of space to allow the birds reaching the feeders and drinkers.

The dermatitis (breast blisters) results obtained in the present study are different from those of Zhao *et al.* (2009), who reported the incidence of breast blisters increased as rearing density increased. It should be noted, however, that skin lesions are closely related with litter and environmental quality, and not only with rearing density.

CONCLUSIONS

1. Cobb 500 broilers presented the highest body weight and daily weight gain throughout the study. However, these parameters were not affected by rearing density and there was no interaction between rearing density and genetic strain ($p \geq 0.05$).

2. Feed conversion ratio and carcass yield were not affected by strain or rearing density ($p \geq 0.05$).

Table 8 – Dermatosis, bruising, dermatitis, arthritis, and femoral degeneration scores of 29-d-old broilers of different strains reared at different densities.

Lesions	Strains	Density (birds/m²)			Mean	p-value
		17	19	21		
Dermatosis	ROSS 808	0.10aB	0.65aA	0.60aA	0.45	
	COBB 500	0.35aA	0.50aA	0.35abA	0.40	0.3376ns
	ROSS 508	0.35aA	0.40aA	0.15bA	0.30	
	Mean	0.27 b	0.52 a	0.37 ab		
	p-value	0.0202*				0.0425*
Bruising	ROSS 808	0.80	0.25	0.30	0.45	
	COBB 500	0.55	0.50	0.05	0.37	>0.05ns
	ROSS 508	0.30	0.30	0.10	0.23	
	Mean	0.55	0.35	0.15		
	p-value	>0.05ns				>0.05ns
Dermatitis	ROSS 808	0.05	0.08	0.00	0.04	
	COBB 500	0.05	0.00	0.00	0.02	0.1286ns
	ROSS 508	0.05	0.00	0.15	0.07	
	Mean	0.05	0.03	0.05		
	p-value	>0.05ns				>0.05ns
Arthritis	ROSS 808	0.10	0.20	0.10	0.13	
	COBB 500	0.10	0.15	0.00	0.08	>0.05ns
	ROSS 508	0.05	0.15	0.10	0.10	
	Mean	0.08	0.17	0.07		
	p-value	0.2567				>0.05ns
Femoral Degeneration	ROSS 808	0.30	0.55	0.40	0.42	
	COBB 500	0.40	0.70	0.40	0.50	>0.05ns
	ROSS 508	0.50	0.85	0.40	0.58	
	Mean	0.40	0.70	0.40		
	p-value	0.1878				0.0621

*significant at 5%; **significant at 1%; means followed by different lowercase letters within a column are statistically different; means followed by different uppercase letters within a row are statistically different.

ns= not significant by ANOVA ($p \geq 0.05$).

3. The evaluated housing densities did not affect the physiological stress indicators ($p \geq 0.05$).

4. Dermatosis score increased ($p \leq 0.05$) as housing density increased from 17 to 19 broilers/m².

5. It is concluded that the housing density of 17 broilers /m² presented the best cost-benefit, because it did not compromise performance parameters, carcass yield or quality, or physiological stress indicators.

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