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The Effect of Cyclic Heat Stress Applied to Different Broiler Chicken Brooding Stages on Animal Performance and Carcass Yield

■Author(s)

Marchini CFP[I] https://orcid.org/0000-0002-9705-072X
Fernandes EA[II] https://orcid.org/0000-0002-5806-3763
Nascimento MRBM[II] https://orcid.org/0000-0003-4324-5262
Araújo EG[III] https://orcid.org/0000-0003-0890-017X
Guimarães EC[IV] https://orcid.org/0000-0001-8328-9687
Bueno JPR[II] https://orcid.org/0000-0001-6177-3187
Fagundes NS[II] https://orcid.org/0000-0001-6281-0779
Café MB[III] https://orcid.org/0000-0002-1478-8009

[I] UNIFRAN - Medicina Veterinária - Rua Rio Grande do Sul, 1795 - Vila Aparecida, Franca, Brasil - 14401324.
[II] Universidade Federal de Uberlândia - Rua Ceará s/n; Bloco 2D; Sala 36, Uberlândia, Minas Gerais, Brazil - 38402-018.
[III] Universidade Federal de Goiás - Escola de Veterinaria e Zootecnia Ringgold standard institution - Escola de Veterinária e Zootecnia Av. Esperança S/N - Campus Universitário Samambaia, Goiânia, Goiás , Brasil - 74690-900.
[IV] Universidade Federal de Uberlândia - FAMEV - Rua Ceará, Bloco 2d , Uberlândia, MG, Brazil - 38499902.

■Mail Address

Corresponding author e-mail address
Cristiane Ferreira Prazeres Marchini
UNIFRAN - Medicina Veterinária - Rua Rio Grande do Sul, 1795 - Vila Aparecida, Franca, São Paulo, Brasil - 14401324.
Phone: +55 16 992199180
Email: cfprazeres@gmail.com

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ABSTRACT

The objective of this study was to evaluate the performance and carcass yield of broilers submitted to heat stress during different rearing stages. A total of 840 one-day-old *Cobb*Avian48™ male broilers were housed in an experimental house equipped with conventional ventilation system and foggers. Birds were distributed according to a completely randomized design into four treatments, with six replicates of 35 birds each. The treatments consisted of: T1 (control) - birds reared under natural temperature and relative humidity conditions from 1 to 42 days of age; T2 - birds submitted to heat stress (HS) from 16 to 21 days of age; T3 - birds submitted to HS from 22 to 42 days of age; and T4 - birds submitted to HS from 16 to 42 days of age. Birds were submitted to heat stress daily for one hour (12:00-13:00h).On day 42, performance data were determined. Six birds per replicate were selected and sacrificed to obtain carcass, parts, and giblet weights and yields. Performance parameters were not influenced by the treatments. Broilers submitted to 1-h cyclic heat between 16 and 42 days of age presented lower deboned breast weight compared with those maintained in natural temperature and relative humidity conditions. It was concluded that the performance of broilers submitted to short cyclic heat periods is not impaired.

INTRODUCTION

Factors such as temperature and air humidity induce changes in bird homeostasis (Lin *et al*., 1996; Yahav *et al*., 2004). Birds above the thermoneutral zone increase heat dissipation to maintain thermal balance. Broiler chickens' growth, development (Mazzi *et al*., 2002) and performance (Borges *et al*., 2003) are impaired under these thermal discomfort conditions, fact that leads to economic losses in the breeding activity.

The exposure to high ambient temperatures is acknowledged for having negative effects on carcass (Oliveira *et al*., 2006a; Oliveira *et al*., 2006b) and noble cut yields (Oliveira *et al*., 2006b). These losses take place because elevated temperatures change energy retention, protein and fat deposition in the carcass, as well as viscera growth (Baldwin *et al*., 1980). Reduced feed intake (by 12.4% and 28%) and decreased weight gain (by 18% and 44%) are among the adverse effects from heat stress recorded for birds bred at 30°C and 35°C, respectively (Al-Fataftah & Abu-Dieyeh, 2007).

Different physiological responses may emerge under heat stress depending on its intensity, severity and duration (Gonzalez-Esquerra & Leeson, 2006). The exposure to heat stress for 50 minutes is sufficient to trigger thermoregulatory response changes in broilers such as hyperthermia (Yanagi Jr. *et al*., 2001). Silva *et al*. (2007) reported increased body temperature and respiratory rate in 42-day-old broiler chickens subjected to 30-minute exposure to high temperatures and relative humidity.

Most studies on the effects of heat stress on broiler performance were conducted in climatic chambers with high ambient temperatures (Oliveira Neto *et al*., 2000; Furlan *et al*., 2001; Rosa et al., 2007) applied are acutely or chronically (Al-Fataftah & Abu-Dieyeh, 2007; Quinteiro Filho *et al*., 2012). However, ambient temperature and air humidity under natural conditions are not constant and may reach high annual values in Brazil, because it is located the tropical zone of the Southern hemisphere. In addition, diurnal variations in air temperature are recorded: it rapidly increases after 08:00, peaks between 12:00 and 15:00, after which it decreases and stabilizes at 21:00 (Silva & Costa, 2000).

Therefore, it is worth investigating the effects from elevated temperatures recorded in conventional poultry house on poultry performance, since studies about heat stress applied to different broiler chicken breeding stages remain scarce.

Therefore, the aim of the current study was to investigate the effects from cyclic heat stress applied for one hour per day during different age periods on the live performance and on carcass, valuable parts and giblet weights and yields of broiler chickens.

MATERIALS AND METHODS

All the procedures adopted in the present study were approved by the Ethics Committee on Animal Use of Federal University of Uberlândia (UFU), Brazil, according to Protocol CEUA/UFU 024/10

The experiment was conducted in the poultry experimentation sector of the afore mentioned university. The poultry house was made of a masonry and metal structure, fiber cement roof, concrete floor covered with wood-shavings litter, open sides covered with plastic canvas curtains, and equipped with foggers and ventilation fans. The house was divided in 24 pens, each equipped with two drinkers each (one automatic nipple drinker and one bell drinker), one tube feeder. An infrared brooder was provided to each four pens.

In this experiment, 840 one-day-old male *Cobb-*Avian48™ broiler chickens were evaluated according to a completely randomized design, with four treatments with six replicates (pens) with 35 birds each at a density of 10.9 birds/m^2. The treatments consisted of four thermal environments: control (natural temperature and humidity conditions) and heat stress from 12:00 to 13:00 submitted during the periods of 16 to 21, 22 to 42 and 16 to 42 days of age.

From one to 14 days of age, all broilers were kept under thermoneutral conditions, and were submitted to the thermal treatments 16 to 42 days of age.

In order to obtain the heat stress environment, double plastic curtains (black and white double-sided canvas) were placed across the poultry house in order to establish four environmental chambers. The fans were kept on during the heat stress period to ensure adequate ventilation.

House temperature (ET) and relative air humidity (RH) were daily monitored 10:00 and 17:00 h, with the aid of a psychrometer Incoterm® (model 5195.03.0.00, Incoterm, Porto Alegre, Brazil) placed in each chamber at 30cm height from the litter.

The chambers were preheated for 10 minutes before the heat exposure period using infrared brooders in order to achieve reach the heat stress temperatures, i.e., temperatures higher than 36 °C. During the heat stress period, chamber environmentaltemperature (ET) and relative humidity (RH) were monitored every 10 minutes using a Portable Digital Thermal Stress Meter (model TGD-200, Instrutherm®, São Paulo, Brazil). Based on the obtained data in each environmental chamber, ET and RH means and standard deviations were calculated for each experimental period (16-21, 22-42 and 16-42 days) and compared with the maximum (ETs handbook) and minimum (ETi handbook) thermal comfort temperatures as function of RH recommended in the genetic strain handbook (Cobb, 2008).

The plastic curtains were opened at the end of the heat stress period to allow ET and RH to return to the natural conditions within 10 minutes. Ventilation fans and foggers were activated to provide thermal comfort conditions when needed.

All the birds received water *ad libitum* and were fed diets formulated according to nutritional levels recommended by Rostagno *et al*. (2005), and based on sorghum, soybean meal, soybean soap stock, dicalcium phosphate, limestone, sodium chloride, vitamin and mineral supplements, and commercial additives. Diets were fed according to 4-phase feeding program as follows: pre-starter (1 to 7 days), starter (8 to 21 days), grower (22 to 33 days) and finisher (34 to 42 days). A lighting light regime of 20 h of light and 2 hours of dark (22L:2D) was applied from 1 to 7 days, 20L:4D from 8 to 21 days, and 22L:20D from 22 to 42 days of age, according to the Cobb handbook (2008). Water and feed were not supplied during the heat stress period.

All birds were weighed on pen basis (35 birds/pen) on a digital scale at 1 and 42 days of age to determine average initial and final body weight, total weight gain, average daily gain.

Feed intake was determined as feed offer minus feed residues and the feeders, and feed conversion ratio as feed intake relative to weight gain, both corrected for mortality, according to Sakomura & Rostagno (2016). Livability was determined as the percentage of live birds at the end of the experimental period relative to the initial number of birds. Production efficiency index was calculated according to the following equation:

PEI = [(DWGxL)÷(FCR)]x100

where: PEI = productive efficiency index; DWG = daily weight gain (kg); L = livability (%); and FCR = feed conversion ratio.

At 42 days of age, all birds in each pen were weighed, and their final average body weight was determined. Next, one bird which body weight was closest to the pen's average BW(± 5%) was selected per pen (6/treatment), submitted to 8-h feed fasting and 4-h fasting, and sacrificed by cervical dislocation. Carcasses were plucked, eviscerated, and absolute (g) and relative (%) carcass weight (with no feet, head and neck) were calculated relative to final BW. The absolute (g) and relative (%) weights of valuable parts (breast with bone, deboned breast, drumstick and thigh, drumette and wingand breast fillet) and of giblets (heart, liver and gizzard) were determined.

Performance and carcass yield data presented normal distribution, according to Shapiro-Wilk test, and were subjected to analysis of variance. Means were compared by Tukey's test. Final body weight and weight gain were subjected to the Kolmogorov-Smirnov test because the data did not present normal distribution as per the Shapiro-Wilk test. Statistical significance was considered at 5% probability level. Statistical analyses were performed using the software SISVAR (Ferreira, 2000).

RESULTS AND DISCUSSION

Figure 1 shows the weekly means and standard deviations of dry-bulb temperatures (ET; °C) and relative humidity (RH; %) measured at 10:00 and 17:00 in the four experimental chambers and the lowest (ETi handbook) and highest (ET s handbook) thermal comfort temperatures recommended by the handbook of the genetic line for each rearing age (days).

The environmental temperature (ET) means recorded during the heat-stress period on days 16-21, 22-28, 29-35 and 36-42 were, respectively, 25.4 °C, 27.8 °C, 26.9 °C and 24.9 °C for the control group, 26.7 °C, 26.1 °C, 26.0 °C and 24.3 °C for the group submitted to heat stress between 16 and 21 days, 25.3 °C, 24.9 °C, 26.5 °C and 24.4 °C for those submitted heat stress between 22 and 42 days and 25.0 °C, 26.5 °C, 26.6 °C and 22.5 °C for those submitted to heat stress between 16 and 42 days of age. These means did not differ from the handbook recommendations for male CobbAvian48™ broilers.

Relative humidity (RU) averages recorded during the heat stress periods at the ages of 16-21, 22-28, 29-35 and 36-42 days were, respectively, 61.6%, 54.9%, 56.8% and 59.3% for the control group, 61.6%, 58.9%, 58.7% and 66.0% for the group submitted to heat stress between 16 and 21 days, 59.9%, 57.7%, 53.8% and 59.4% for those submitted heat stress between 22 and 42 days and 75.6%, 65.0%, 64.6% and 75.5% for those under heat stress between 16 and 42 days of age.

These results shows that male CobbAvian48™ broiler chickens were kept in thermoneutral conditions from 1 p.m to 12 p.m. during the experimental period and that the RU were similar in all groups.

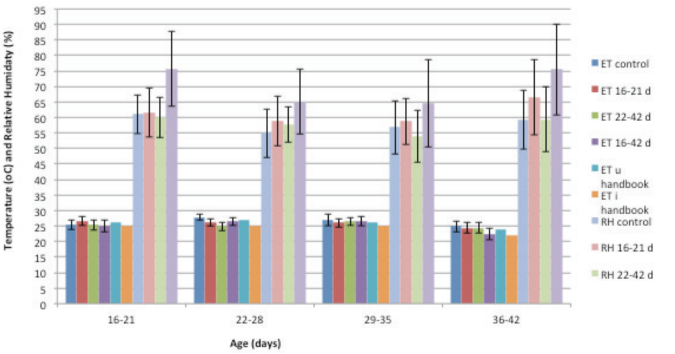

Figure 1 – Weekly environmental temperature and relative humidity measured under natural conditions.

The means of ET recorded during the heat stress period at 16-21, 22-28, 29-35 and 36-42 days were, respectively, 30.0 °C, 27.2 °C, 26.1 °C and 25.4 °C for the control group, 35.5 °C, 28.9 °C, 25.8 °C and 24.1 °C for the group submitted to heat stress between 16 and 21 days, 30.9 °C, 35.4 °C, 36.5 °C and 36.2 °C for those submitted heat stress between 22 and 42 days and 35.4 °C, 35.9 °C, 36.8 °C and 36.8 °C for those submitted to heat stress between 16 and 42 days of age. These means shows that broilers were submitted to ET above the thermoneutral zone during the heat stress period, from 12:00 to 13:00.

Figure 2 shows the weekly means and standard deviations of dry-bulb temperatures (ET; °C) and relative humidity (RH; %) measured during the 1-h heat exposure period in the four experimental chambers and the lowest (ETi handbook) and highest (ET s handbook) thermal comfort temperatures recommended by the handbook of the genetic line for each rearing age (days).

Relative humidity average recorded during the heat stress period (12:00 to 13:00) at the ages of 16-21, 22-28, 29-35 and 36-42 days were, respectively, 42.4%, 50.4%, 53.2% and 46.6% for the control group, 35.1%, 50.9%, 57.6% and 56.4% for the group submitted to heat stress between 16 and 21 days, 31.0%, 46.0%, 47.4% and 39.8% for those submitted heat stress between 22 and 42 days and 36.5%, 43.6%, 45.6% and 46.2% for those under heat stress between 16 and 42 days of age.

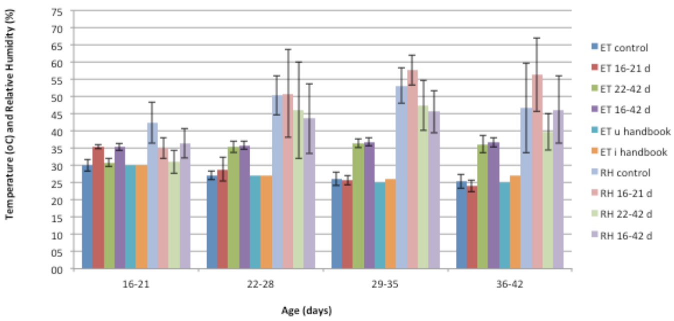

Figure 2 – Weekly environmental temperature and relative humidity measured during the heat exposure period.

The ET temperature differences were recorded between the heat-stress period (from 12:00 pm to 01:00 pm) and the period when birds were kept under natural temperature and humidity conditions (from 01:00 pm to 12:00 am in the following day) was 10.13 °C, on average (Figure 2). According to Donald (1997), birds are able to withstand higher daytime temperatures when the temperature difference between the day and night periods is at least 10 °C, allowing the dissipation of the body heat accumulated during the day. However, when the temperature does not sufficiently decrease during the night, birds are not able to dissipate the heat accumulated during the day, which may negatively may affect their performance and increase their mortality (Lara & Baião, 2005).

Performance parameters

The initial average body weight at the beginning of the experiment (16-d-old) were determined as 464.0 ± 9g for the control group, and 467.7 ± 9g, 453.0 ± 9g and 453.0 ± 9g for groups subjected to heat stress between 16-21, 22-42, and 16-42 days of age, respectively.

There was no effect of the treatments ($p>0.05$) on the evaluated performance parameters male *Cobb*Avian48™ (Table 1). This result may be partially explained by the fact that, after the heat stress period, natural temperature and humidity conditions were resumed with the activation of fans and foggers to provide a thermally comfortable environment. In addition, during the evening and throughout the night, environmental conditions were within comfortable limits, favoring feed intake. The ability of birds to dissipate heat during the coolest period of the day is one of the main differences between constantly high temperatures and those cyclic hot temperatures (Leone *et al*., 2001; Ribeiro *et al*., 2001), as broilers kept under constant heat stress are unable to reestablish homeothermy, which impairs their performance (Dionello *et al*., 2002; Abu-Dieyeh 2006; Oliveira *et al*., 2006a). One-hour heat exposure is enough to cause physiological changes, such as increase in body temperature and respiratory rate (Yanagi *et al*., 2001; Silva *et al*., 2007); however, the high cyclic temperatures to which broilers were subjected in the present study were not severe and prolonged enough to negatively impact their performance. Moreover, the adopted lighting regime enabled birds to have access to food and water during night, which may have allowed them recover from the effects of the one-

Table 1 – Average performance results of 42-day-old male reared under natural environmental conditions or exposed to 1-h cyclic heat stress for different age periods.

	Heat exposure ages (days)				CV (%)	P value
	Control	16 to 21	22 to 42	16 to 42		
Final BW (g)	2.829	2.867	2.806	2.861	2.64	0.479
WG (g)	2.781	2.820	2.759	2.812	2.69	0.481
ADWG(g)	66.22	67.13	65.69	66.96	2.69	0.484
FI (g)	4.725	4.706	4.713	4.687	2.82	0.965
ADFI (g)	112.5	112.0	112.2	111.6	2.82	0.965
FCR	1.69	1.66	1.71	1.66	2.15	0.134
Livability (%)	98.57	97.69	96.72	98.09	2.09	0.468
PEI*	390.7	399.6	378.1	401.3	3.74	0.050

Different lowercase letters on the lines differ from each other, according to the Tukey test ($p<0.05$).

WG: weight gain; ADWG: average daily weight gain; FI: feed intake; ADFI: average daily feed intake; FCR: feed conversion ratio; PEI: production efficiency index hour heat stress to which they were subjected during the day. Therefore, the final body weight, weight gain, average daily weight gain, feed intake, average daily feed intake, feed conversion ratio, livability and production efficiency index of the heat-stress broilers were statistically similar to those recorded in broilers maintained under constant natural temperature and humidity conditions.

The results of the current experiment corroborate with those reported by Akşit *et al*. (2006), who did not find any effect of cyclic heat stress (28 °C from 10:00 to 17:00 and 22 °C from 17:00 to 10:00 between 3 and 7 weeks of age) on the broiler body weight and feed intake.

However, the weight gain, feed conversion ratio and mortality results obtained in the present study differed from those recorded by Quinteiro Filho *et al*. (2010) and Mello *et al*. (2015), who reported that these parameters were impaired in broilers subjected to cyclic heat stress (36 °C, 10 hours a day, at 35-42 days of age) or to continuous heat stress (32°C ± 0.5 °C, for 72 hours at 4 and 6weeks of age), respectively. Salabi *et al*. (2011), differently from the present results, reported lower feed intake and weight gain, as well as worse feed conversion ratio in broiler chickens subjected to cyclic heat stress (37°C for six hours at 45% relative humidity) from 3 to the 7 weeks of age. These differences may be attributed to the fact that the aforementioned authors applied longer heat stress periods and housed birds in climatic chambers, whereas in the present experiment, birds were exposed only to 1-h heat stress and were housed in a conventional shed.

According to Hurwitz *et al*. (1980), high mortality rates are recorded when the ambient temperature exceeds 38 °C. The highest mean temperature recorded during heat stress in the current experiment was 36.8 °C applied for one hour after day 28 in birds exposed to heat stress from 16 to 42 days of age (Figure 2). Altan *et al*. (2000) reported that the livability of fast-growing broilers subjected to 38 °C for 24 hours between1 and 35 days of age was not compromised, which temperature is more challenging than those used in the current experiment.

The differences in environmental conditions, bird age during heat stress exposure, and individual variations among studies may explain the variable responses reported in literature. In addition, most studies on the effects of heat stress on broiler performance were conducted in climatic chambers, which temperature and relative humidity conditions are different from those under natural rearing conditions recorded in open-sided poultry houses, according to May & Lott (2000).

Cyclic heat stress did not influence (p>0.05) the evaluated carcass, valuable parts, and giblets yields, except for absolute boneless breast weight (p<0.05) of the birds exposed for the longest period, i.e., from 16 to 42 days of age, which was 16.14% lighter compared with that of the control birds (Table 2). This result may be explained by changes in protein metabolism caused by heat stress, which reduces protein synthesis and increases breast muscle fiber catabolism rate (Zhang *et al*., 2012). It should be emphasized that breast weight reduction is undesirable due to the high economic value of this part. According to Fernandes *et al*. (2002), chicken breast is an important part of the consumer market, since it results in higher economic compensation in comparison with other carcassparts. Average absolute boneless breast weights, however, were not different among broilers submitted to cyclic heat stress.

The current study demonstrated that the exposure of broilers to cyclic heat stress differently influenced their muscles. Heat stress did not influence drumstick and thigh weight compared with bone-in and deboned breast weights, indicating the possible prioritization of protein deposition in the drumstick and thigh muscles relative to the breast muscle. This may be explained by the characteristics of the muscle fibers of each muscle group. Broiler breast muscle (*Pectoralis major*) consists of type-IIb fibers (fast contraction myoglobin-poor glycolytic fibers) and require low blood supply and oxygen. These fibers easily fatigable that accumulate lactic acid and have low metabolic and oxygen exchange rates (Banks, 1992; Ono *et al*., 1993; Rosser *et al*., 1996). On the other hand, type-I fibers are predominant in the drumstick and thigh muscles. Type-Ifibers are myoglobin-rich, oxidative, present slow contraction and require high blood and oxygen supply (Ono *et al*., 1993; Rosser *et al*., 1996).

Heat stress may also exert different effects on different muscle fiber types due to action of corticosterone, which levels are higher when animals are maintained at elevated temperatures, and its catabolic effects on glycolytic fibers are more pronounced than on oxidative fibers in mammals (Silva, 2002). In addition, muscle growth mainly depends on the hypertrophy of glycolytic fibers (Sartori *et al*., 2003), which are predominant in the breast of broiler chickens (Rosser *et al*., 1996). Therefore, the results suggest that the effect of heat stress on the carcass muscles of broilers may vary according to the predominant type of muscle

Table 2 – Absolute weights and yields of the carcass, valuable parts, and giblets of 42-day-old male *Cobb*Avian48TM broilers reared under natural temperature and humidity conditions (control) or submitted to 1-h cyclic heat stress for different age periods.

	Heat exposure age (days)				CV (%)	*p* value
	Control	16 to 21	22 to 42	16 to 42		
Absolute weights (g)						
LW	2.874	2.780	2.779	2.726	3.96	0.170
C-FHN	2.053	1.986	2.003	1.911	4.30	0.065
Breast with bone	740.0	733.0	755.0	697.0	4.97	0.072
Deboned breast	570.0a	505.0ab	528.0ab	478.0b	8.46	0.013
Drumstick and thigh	0.638	0.613	0.606	0.603	6.37	0.422
Drumette and wing	0.222	0.222	0.208	0.208	6.31	0.122
Breast Fillet**	0.105	0.107	0.106	0.098	8.88	0.321
Gizzard	0.036	0.039	0.032	0.035	13.29	0.113
Liver	0.051	0.048	0.048	0.044	9.11	0.074
Heart	0.013	0.011	0.012	0.013	13.74	0.143
Carcass yield - Relative weight(%)						
C-FHN	71.44	71.44	72.10	70.11	2.34	0.244
Breast with bone*	36.06	36.99	37.72	36.50	4.96	0.455
Deboned breast	27.76	25.54	26.40	25.04	8.93	0.229
Drumstick and thigh	31.01	30.83	30.26	31.60	4.63	0.453
Drumette and wing	10.83	11.18	10.41	10.91	4.49	0.081
Breast fillet**	18.75	21.38	20.20	20.54	10.27	0.203

Lowercase letters on the lines differ from each other, according to the Tukey test ($p<0.05$).

LW (live weight); C-FHN (carcass without feet, head and neck). **Pectoralis major*and*Pectoralis minor*muscles. ** *Pectoralis minor*muscle.

fibers composing the different commercial parts. Moreover, the respiratory rate of broilers increases during cyclic heat stress, as reported by Marchini *et al*. (2007), leading to greater breast muscle fiber activity (Faria Filho *et al*., 2006) and glycogen depletion, which is the main energy source of muscles (Geraert *et al*., 1996; Akşit *et al*., 2006). This may also explain the lower absolute breast weight observed in the broilers submitted for cyclic heat stress for a longer age period.

The current results are consistent with reports of Plavnik & Yahav (1998), who subjected male broilers to cyclic heat stress (35 °C, from 07:00 to 17:00 between 4 and 8 weeks of age) and recorded an 8% breast weight reduction in comparison with birds kept under thermal comfort condition (25 °C). Salabi *et al*. (2011) also did not find any differences in liver weight and thigh yield between broilers exposed to heat stress (37 °C for 6 hours at 45% RH) between 3 and 7 weeks of age and those kept in thermoneutral environments.

The obtain giblet results are different from those reported by Oliveira *et al*. (2006a), who found a decrease in absolute and relative gizzard, heart and liver weights in broiler kept in a climatic chamber under chronic heat stress (32 °C) for 24 hours between 22 and 42 days of age.

The comparison among studies on the effects of heat stress on broiler performance and carcass parameters is limited by the lack of an accurate index that effectively describes heat stress degrees to which birds are subjected under experimental conditions. In addition, most studies do not differentiate short- from long-term responses to hyperthermia (Gonzalez-Esquerra & Leeson, 2006).

Different physiological responses developed by broilers subjected to heat stress may negatively influence their productive performance. These responses depend on the duration of heat-stress exposure and the age at which birds experienced the stress stimulus. According to Rosa *et al*. (2007), the age at which the heat stress is applied to the animals plays an important role in their responses to stress.

CONCLUSION

The cyclic heat stress applied to male broilers for one hour did not impair their performance, regardless of the age periods of exposure; however, breast weight was reduced when it was applied between 16 and 42 days of age.

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