ea engenharia agrícola

Journal of the Brazilian Association of Agricultural Engineering

ISSN: 1809-4430 (on-line)

DETERMINATION OF THERMAL COMFORT ZONE FOR EARLY-STAGE BROILERS[1]

Doi:http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v36n5p760-767/2016

MÁRCIA G. L. CÂNDIDO[2*], ILDA DE F. F. TINÔCO[2], FRANCISCO DE A. DE C. PINTO[2], NERILSON T. SANTOS[2], RICARDO P. ROBERTI[3] (*in memoriam)*

ABSTRACT: Environmental temperatures currently considered within comfort zone for broiler rearing may be misleading or even obsolete from actual values. Some factors such as animal genetics, nutrition and poultry management, mainly acclimatization to tropical and subtropical conditions, influence in determining the comfort zone for birds. This study aimed to evaluate the effects of five different thermal environments on animal welfare and rearing performance of broiler chickens, setting an ideal temperature range (comfort zone) for each of the first three weeks of poultry breeding. The chicks (375) were randomly placed into five climatic chambers set to distinct thermal conditions, being: one as recommended by the literature, another as stated by CASSUCE and the other three at different levels of apparent cold stress (mild, moderate and severe). The findings showed that best poultry performance and ideal comfort indices (based on Black Globe Humidity and Temperature Index) were achieved within a temperature range between mild cold and CASSUCE comfort temperature, rather than those previously reported in the literature.

KEY WORDS: poultry, thermal comfort, animal performance, cold stress.

INTRODUCTION

Ambience in contemporary poultry is strictly related to thermal comfort of birds, which, for being homeothermic animals, have their body temperature influenced by the environment to which are exposed (FURTADO et al., 2010; ABREU et al., 2012; SOUZA et al., 2014). Therefore, the thermal environment, which encompasses temperature, humidity, air speed and radiation, interferes directly with breeding performance, changing food consumption and welfare of animals (PONCIANO et al., 2011; PONCIANO et al., 2012; SANTOS et al., 2014). Accordingly, environment inside the aviary sheds must be controlled so that the birds can be reared within a thermal comfort zone, avoiding negative thermal effects on animal yield (ALMEIDA & PASSINI, 2013; CORDEIRO et al., 2010; ROCHA et al., 2010; CAMPOS et al., 2013).

Temperature variation in broiler rearing sheds that have been currently employed and considered as optimal for poultry production might be outdated, since there have been several changes in animal genetics, nutritional standards, management and acclimatization of birds (CASSUCE et al., 2013).

By assessing broiler performance under diverse climatic conditions, CASSUCE et al. (2013) noted that birds remained within a temperature range below the previously recommended as ideal in literature showed better performances. These authors also highlighted the need for refining the data on temperature ranges for comfort conditions, suggesting further investigations towards other thermal bands of the environment.

Given the above and considering the period from 1 to 21 days of broiler life, within which birds are most vulnerable to cold-related problems, the aim of this study was to evaluate the effect of five distinct thermal environments on poultry performance (weight gain, feed intake and feed conversion of broiler chicks). Thus, focusing on updating the thermal zone limits for these animals, allowing optimization of energy consumption required to heat the aviary sheds.

---

[1] Parte da dissertação de mestrado do primeiro autor.

[2] Universidade Federal de Viçosa/Viçosa, Brasil.
[3] Pif Paf Alimentos/Visconde do Rio Branco, Brasil.
*Corresponding author. E-mail: marciagl.candido@gmail.com

Received in: 8-14-2015
Accepted in: 5-28-2016

MATERIAL AND METHODS

All procedures used in this experiment were approved by the Institutional Animal Care and Use Ethics Committee (CEUA) of the Federal University of Viçosa (UFV), in Minas Gerais state, Brazil, under protocol n° 110/2013.

The experiment was performed during the months of January and February of 2014, using climatic chambers located in the experimental area of the Research Center for Ambience and Engineering of Agro-industrial Systems (AMBIAGRO), belonging to the Rural Construction and Ambience of the Federal University of Viçosa, in Viçosa - MG, Brazil.

Evaluations were conducted on 375 one-day-old male broiler chicks of Cobb strain, which were from the same mother nursery and hatchery, weighting initially 45.4g. Immediately after arrival from hatchery, birds were housed and randomly distributed into five climatic chambers.

Chambers had dimensions of 3.5 m length x 2.5 m width x 2.5 height. They had been previously heated by means of heaters (AB Split 1, Britânia, Brazil) already installed inside the facilities. Temperature remained at 33°C, as recommended in literature studies and currently used by Brazilian breeders, being stated as ideal to receive chicks to lodgings (CURTIS, 1983; BAÊTA & SOUZA, 1997; CORDEIRO et al., 2011; MENEGALI et al., 2013). Air was renewed through two AMB system axial fans (model FD 08025S1M; DC 12V, 0.15A).

The one-day-old chicks were housed at a stocking density of 30 birds per m², which was gradually reduced, in line with commercial standards, to 24 birds per m² from 7 to 14 days and to 20 birds per m² from 15 to 21 days. The animals were kept inside cages with dimensions of 0.5 m width, 1.0 m length and 0.5 m height, placing six units per chamber. In order to reproduce field conditions during settling period, an 8-cm coffee hull bed covered cage floor.

Five thermal ranges were set (air temperature), which made up each of the five treatments, being conducted from the second to the 21st day of chick rearing (Table 1).

TABLE 1. Description of the thermal treatments performed during the 1st, 2nd and 3rd weeks of broiler chick rearing, respectively.

Treatment description		T(ºC) 1st week	T(ºC) 2nd week	T(ºC) 3rd week
TCL	Thermal comfort recommended in literature	33	30	27
TCC	Thermal comfort updated by CASSUCE et al. (2013)	30	27	24
MiC	Mild cold stress	27	24	21
MoC	Moderate cold stress	24	21	18
SeC	Severe cold stress	21	18	15

TCL: Thermal comfort range set by international literature (CURTIS, 1983; CHENG et al., 1997); TCC: Thermal comfort range updated by CASSUCE et al., (2013); MiC: Apparent thermal range of mild cold stress; MoC: Apparent thermal range of moderate cold stress; SeC: Apparent thermal range of severe cold stress; all given for each of the three first weeks of broiler rearing

The air relative humidity was maintained close to 60%, ranging between 55 and 65% for being considered suitable for poultry during this rearing period according to BAÊTA & SOUZA (1997) and VIGODERIS et al. (2010).

Dataloggers (HOBO U14-001, Onset, USA) recorded air temperature and humidity inside chambers automatically, at a resolution of 0.1 °C (temperature) and 1% (humidity), and accuracy of ±0.5 °C (temperature) and ±1% (humidity). Based on the records, the Black Globe Humidity and Temperature Index (BGHI) indices were calculated by means of the Equation 1 (BUFFINGTON et al., 1981).

$$BGHI = BGT + DPT\,(0.36) + 41.5 \tag{1}$$

where,

BGT = black globe temperature, in °C;

DPT = dew point temperature, in °C.

Water and feed were provided twice a day to birds, keeping drinking and feeding troughs always stocked. For that, two commercial feeds were used throughout the experiment, providing pre-starter feeds to 1 to 7 day-old chicks, and starter feed to 8 to 21 day-old ones.

The variables used to measure animal performance were weight gain (WG), in grams; feed intake (FI), calculated as the difference between the feed provided plus leftovers, during the experiment period; food conversion (FC), weekly and total, consisting of the ratio between weight gain and feed intake.

The effect of environmental temperature on these variables was measured by regression analysis in each experimental week. These calculations were made using R-language (free software environment for statistical computing and graphics) (R Core Team, version 0.98.1091) for the Windows desktop operating systems.

RESULTS AND DISCUSSION

First week data

According to the regression analysis, despite the birds fed more (high FI), environmental temperature had no significant effect on animal weight and WG ($p<0.05$). This increasing intake of birds subjected to cold stress is due to a higher requirement for energy to generate heat for body temperature maintenance. Therefore, as energy is forwarded to heat generation, animals do not gain weight, which hinders FC (BAÊTA & SOUZA, 1997; CAMPOS et al., 2013; CASSUCE et al., 2013).

Figure 1 shows the averages of FC according to treatments, as well as the adjusted model by regression analysis for the first rearing week. During this first period, the ambient temperature that enhanced FC was 27 °C (MiC), which was 2 °C below the finding of PONCIANO et al. (2012). It was also different from estimates of CASSUCE et al. (2013), who reported a temperature of 31.3 °C, expressing lower FC in one-week-old chicks. This variation might have occurred because in the experiment run by CASSUCE et al. (2013), cage floors were not covered with poultry litter; once such substrates assist in slowing down heat and hence contributing to animal thermal comfort, without thermal abrupt changes. Moreover, the bedding remains constantly warmer due to leavening reactions which release heat and, as it is in direct contact to poultry legs, it significantly improves the sense of thermal comfort.

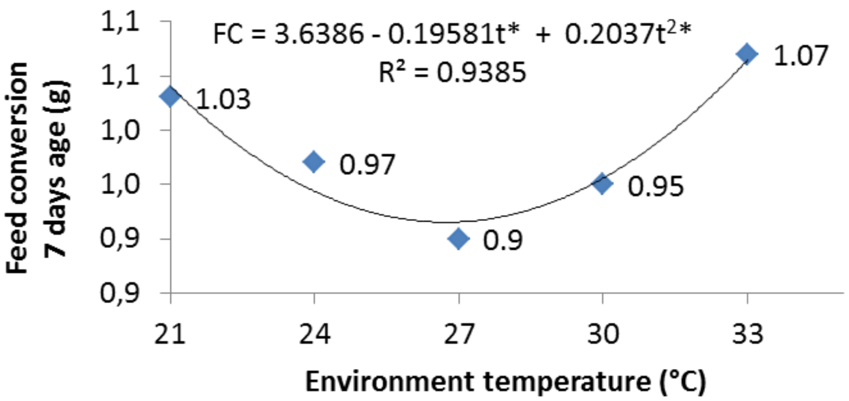


FIGURE 1. Feed conversion ratio at different environment temperature levels during the first rearing week of broiler chicks. *($p<0.05$)

Second week data

Figure 2 shows the averages of body weight (BW) according to each condition and the respective adjusted model, by regression analysis, for the second rearing week of broiler chicks. In this week, the temperature promoting the highest BW was 24.5 °C, which confirms the findings of CASSUCE et al. (2013).

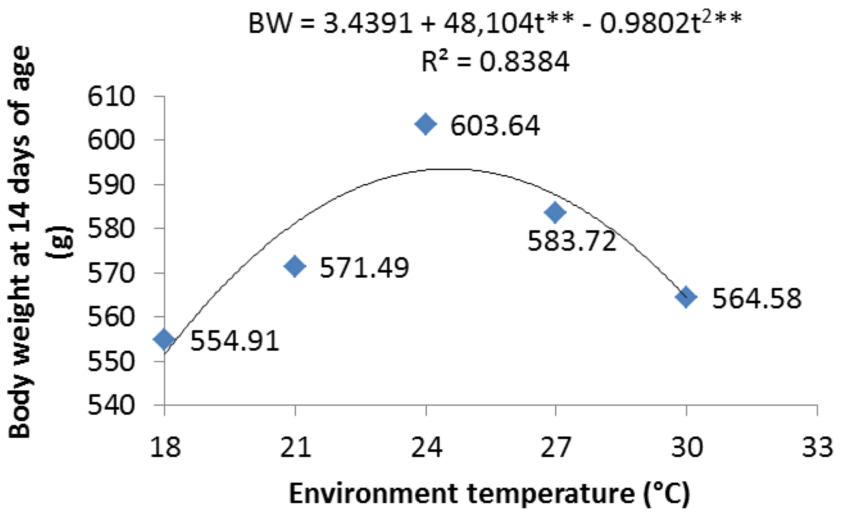
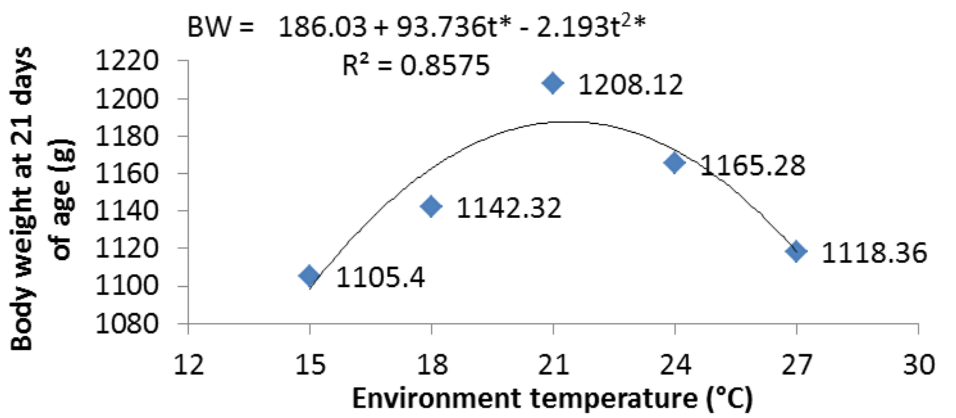


FIGURE 2. Broiler body weight at different environment temperature levels during the second rearing week of broiler chicks. **(p<0.1)

PONCIANO et al. (2012) reported a weight gain of 359.7g for animals kept at 28.19 °C and 80% air humidity; this WG is superior to the values found for MiC and TCC. Differently, PONCIANO (2011) found FI rates (1.30) higher than the ones found in here, if compared to TCC (1.26) and MiC (1.20) treatments (Table 2). In this sense, although WG values checked here and by CASSUCE et al. (2013) were inferior to those reported by PONCIANO et al. (2012); the birds had a production efficiency improved. This factor can be measured by FC that is the ratio between WG and FI. Actually, the above-mentioned difference may be related to higher humidity in the environment studied by PONCIANO et al. (2012), what surely affects FC rates. With increasing air humidity, the evaporative cooling is less efficient, hampering heat dissipation by birds, which makes the animals become agitated and dispersed, hindering performance due to worsening of FC (OLIVEIRA et al., 2006).

Third week data

Figure 3 (A) displays the averages of BW according to each temperature, and the respective adjusted model by regression analysis for the third rearing week. And Figure 3 (B) shows the averages of WG at each temperature and respective regression model.



(A)

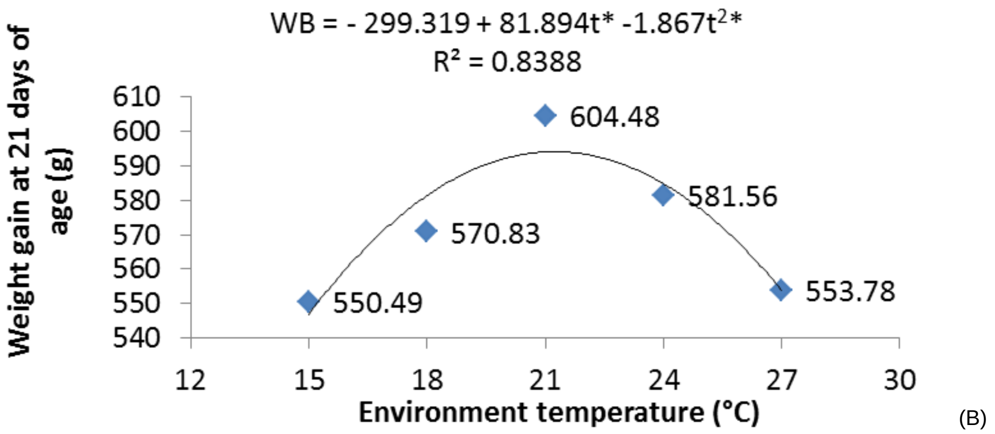


FIGURE 3. Broiler body weight (A) and weight gain (B) at different environment temperature levels during the second rearing week of broiler chicks. * ($p<0.05$)

On the third week, the largest WG was observed in chicks subjected to MiC, exceeding by 8% the gain observed for TCL, which had been considered to date the ideal for the first phase of broiler rearing. These results are in agreement with those found by CASSUCE et al. (2013); according to these authors, the ideal temperature for chickens in the third week is 21.8 °C, therefore, near to the estimate of this experiment (21.1 °C).

Cumulative performance of broilers until the twenty-first day of age

Table 2 introduces the averages of cumulative performance of the birds throughout the three first weeks of trial, from 1 to 21 days of age, for each of the tested thermal environments.

TABLE 2. Averages of cumulative weight gain (WG), body weight (BW), feed intake (FI), and feed conversion (FC) obtained from 21-day-old broilers under different thermal environments.

Thermal environment	Animal response			
	WG (g bird)	PV (g bird)	FI (g)	FC
Literature approach (TCL)	1073.54	1118.36 ± 5.2	1368.17	1.27
CASSUCE update (TCC)	1119.82	1165.28 ± 4.7	1413.49	1.26
Mild Cold (MiC)	1171.02	1215.39 ± 5.6	1401.47	1.20
Moderate Cold (MoC)	1096.76	1142.32 ± 4.6	1467.21	1.34
Severe Cold (SeC)	1058.57	1105.40 ± 6.0	1418.13	1.34

The final performance of birds under MiC was better than the other treatments, for both WG and FC. It can be inferred, then, that during the first 21 days, this treatment stood out concerning productive performance of the broilers, i.e., providing better thermal comfort and welfare to the animals.

When exposed to SeC, chicks consumed up to 19% more feed compared to the other treatments, showing that under cold stress birds tend to increase FI to raise heat production (BAÊTA & SOUZA, 1997; CAMPOS et al., 2013; CASSUCE et al., 2013). Nevertheless, this increased FI was not converted into WG because the animals of this group tend to have lower BW than those used in the other treatments.

BGHI values denoting the best conditions for a good productive performance of broilers within the first three weeks of rearing

Table 3 shows the averages of temperature and air relative humidity with respective standard errors, as well as the corresponding mean indices of Black Globe Humidity and Temperature Index (BGHI), with standard deviation and variation coefficient, for each treatment.

TABLE 3. Weekly averages and standard deviations of air temperature (T), air relative humidity (RH) and black globe humidity and temperature index (BGHI) with coefficient of variation (CV) inside the climatic chambers until the 3rd week of life of broilers: thermal comfort taken from literature (TCL), thermal comfort updated by CASSUCE (TCC), mild cold stress (MiC), moderate cold stress (MoC) and severe cold (SeC) for the period experimental.

		1st week		
Thermal environments	T (°C)	RH (%)	BGHI	BGHI – CV(%)
TCL	33.0 ± 0.5	64.8 ± 5.3	83.6 ± 0.9	1.06
TCC	30.0 ± 0.5	60.8 ± 5.2	79.7 ± 1.6	1.94
MiC	27.0 ± 0.5	58.2 ± 3.5	75.8 ± 1.0	1.28
MoC	24.0 ± 0.5	58.7 ± 3.7	72.3 ± 1.4	1.97
SeC	21.0 ± 0.5	63.6 ± 4.8	70.5 ± 1.7	2.51
		2nd week		
Thermal environments	T (°C)	RH (%)	BGHI	BGHI – CV (%)
TCL	30.0 ± 0.3	60.3 ± 5.7	79.9 ± 0.8	1.01
TCC	27.0 ± 0.6	59.5 ± 3.8	74.4 ± 1.8	2.46
MiC	24.0 ± 0.3	57.1 ± 3.5	71.8 ± 0.8	1.16
MoC	21.0 ± 0.5	66.8 ± 5.2	68.7 ± 0.4	0.56
SeC	18.0 ± 0.5	64.2 ± 4.5	64.6 ± 0.6	0.96
		3rd week		
Thermal environments	T (°C)	RH (%)	BGHI	BGHI – CV (%)
TCL	27.0 ± 0.3	59.6 ± 4.8	76.5 ± 0.6	0.77
TCC	24.0 ± 0.4	56.4 ± 2.8	71.7 ± 0.4	0.60
MiC	21.0 ± 0.6	65.6 ± 3.3	68.6 ± 1.0	1.45
MoC	18.0 ± 0.7	64.5 ± 5.4	65.0 ± 1.0	1.49
SeC	15.0 ± 0.5	65.1 ± 4.8	62.8 ± 0.5	0.82

According to OLIVEIRA et al. (2006), the BGHI indices that typify a pleasant thermal environment for birds vary from 77.0 to 80.0 within the first week; however, such range is between 73 and 76 during the second and third weeks. In the present study, the BGHI values were above those shown by those authors for birds under TCL. Thus, even though TCL indices have been foreboded in literature for broiler at these ages, they are indeed above the ideal range.

Studying broiler chickens, CELLA et al. (2001) found BGHI ranges of 77 to 81, 75 to 77 and 72 to 75 for the first, second and third weeks of age, respectively, as indicatives of thermal comfort. Once again, BGHI ranges found for TCL in our study study were consistently above those said as optimal, thus featuring a heat stress.

As a result, solely TCC and MiC could promote BGHI values that stood within the comfort zone for broilers, as stated by the mentioned authors. This way, regarding this index, the remaining treatments caused heat stress by cold to the animals.

CONCLUSIONS

Under the conditions of this experiment, the ranges of temperature that promoted thermal comfort to broiler chickens during this first rearing stage were different from those hitherto recommended as ideal in literature. The optimum range for the first, second and third week of bird life remained between treatments MiC (27, 24, and 21 °C) and TCC (30, 27 and 24 ° C). Whereas BGHI ranges were of 75.8 ± 1.0 to 79.7 ± 1.6; 71.9 ± 0.9 to 74.4 ± 1.8; and 68.7 ± 1.0 to 71.7 ± 0.4 for the first, second, and third weeks, respectively.

ACKNOWLEDGEMENTS

To CAPES, CNPq, FAPEMIG and the PIF PAF Alimentos S.A.

REFERENCES

ABREU, P. G.; ABREU, V. M. N.; COLDEBELLA, A.; HASSEMER, M. J.; TOMAZELLI, I. L. Medidas morfológicas em função do peso e da idade da ave, por meio de imagens. **Revista Brasileira de Engenharia Agrícola e Ambiental,** Campina Grande, v. 16, n. 7, p. 795-801, 2012. Disponível em: <http://www.agriambi.com.br>. doi: 10.1590/S1415-43662012000700014. Acesso em: 20 dec. 2014.

ALMEIDA, E. A.; PASSINI, R. Thermal comfort in reduced models of broilers houses, under different types of roofing materials. **Engenharia Agrícola**, Jaboticabal, v. 33, n. 1, p. 19-27, 2013. Disponível em: < http://www.engenhariaagricola.org.br/>. doi: 10.1590/S0100-69162013000100003. Acesso em: 07 nov. 2014.

BAÊTA, F. C.; SOUZA, C. F. **Ambiência em edificações rurais - conforto animal**. Viçosa: UFU, 1997. 246 p.

BUFFINGTON, D. E.; COLAZO-AROCHO, A.; CANTON, G. H; PITT, D.; THATCHER, R. J.; COLLIER, R. J. Black globe humidity index (BGHI) as comfort equation for dairy cows. **Transaction of American Society of Agricultural Engineering**, St. Joseph, v. 24, p. 711-714, 1981.

CAMPOS, A. T.; KLOSOWSKI, E. S.; SOUSA, F. A.; PONCIANO, P. F.; NAVARINI, F. C.; YANAGI JUNIOR, T. Eficiência de sistema de aquecimento auxiliar para aviários, com base nos índices de conforto térmico. **Bioscience Journal**, Uberlândia, v. 29, n. 3, p. 703-711, 2013.

CASSUCE, D. C.; TINOCO, I. D. F.; BAETA, F. C.; ZOLNIER, S.; CECON, P. R.; VIEIRA, M. D. A. Thermal comfort temperature update for broiler chickens up to 21 days of age. **Engenharia Agrícola**, Jaboticabal, v. 33, n. 1, p. 28-36, 2013.

CELLA, P. S.; DONZELE, J. L.; OLIVEIRA, R. F. M.; ALBINO, L. F. T.; FERREIRA, A. S.; GOMES, P. C.; VALERIO, S. R.; APOLONIO, L. R. Níveis de lisina mantendo a relação aminoacídica para frangos de corte no período de 1 a 21 dias de idade, em diferentes ambientes térmicos. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 33, n. 2, mar./apr. 2001.

CHENG, T.K.; HAMRE, M.L.; COON, C.N. Effect of environmental temperature, dietary protein, and energy on broiler performance. **Journal Applied of Poultry Science**, Athens, v.6, p.1-17, 1997. Disponível em: <http://japr.oxfordjournals.org/>. doi: 10.1590/S1516-635X2005000400009. Acesso em: 12 may 2014.

CORDEIRO, M. B.; TINÔCO, I. F.; ROQUE FILHO, M.; SOUSA, F. C. D. Digital image analysis for young chicken's behavior evaluation. **Engenharia Agricola**, Jaboticabal, v. 31, n. 3, p. 418-426, 2011.

CORDEIRO, M. B.; TINÔCO, I. F. F.; SILVA, J. N.; VIGODERIS, R. B.; PINTO, F. A. C.; CECON, P. R. Conforto térmico e desempenho de pintos de corte submetidos a diferentes sistemas de aquecimento no período de inverno. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 39, n.1, p. 217-224, 2010.

CURTIS, S. E. **Environmental management in animal agriculture**. Dmes: Iowa State University Press, 1983.

FURTADO, D. A.; ROCHA, H. P.; NASCIMENTO, J. W. B.; SILVA, J. H. Índices de conforto térmico e concentrações de gases em galpões avícolas no semiárido paraibano. **Engenharia Agrícola**, Jaboticabal, v. 30, n. 6, p. 993-1002, 2010.

MENEGALI, I.; TINÔCO, I. F. F.; CARVALHO, C. C. S.; SOUZA, C. F.; MARTINS, J. H. Comportamento de variáveis climáticas em sistemas de ventilação mínima para produção de pintos de corte. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 17, n. 1, p. 106-113, 2013.

OLIVEIRA, R. F. M.; DONZELE, J. L.; ABREU, M. L. T.; FERREIRA, R. A.; VAZ, R. G. M. V.; CELLA, P. S. Efeitos da temperatura e da umidade relativa sobre o desempenho e o rendimento de cortes nobres de frangos de corte de 1 a 49 dias de idade. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 35, n. 3, p. 797-803, 2006. Disponível em: < http://www.revista.sbz.org.br/> .doi: 10.1590/S1516-35982006000300023

PONCIANO, P. F.; JUNIOR, T. Y.; SCHIASSI, L. Sistema fuzzy para predição do desempenho produtivo de frangos de corte de 1 a 21 dias de idade. **Engenharia Agricola**, Jaboticabal, v. 32, n. 3, p. 446-458, 2012.

PONCIANO, P. F.; LOPES, M. A.; YANAGI JUNIOR, T.; FERRAZ, G. A. S. Análise do ambiente para frangos por meio da lógica fuzzy: uma revisão. **Archivos de Zootecnia**, Córdoba, v. 60, n. 1, p.1-13, 2011.

ROCHA, H. P.; FURTADO, D. A.; NASCIMENTO, J. W. B.; SILVA, J. H. V. Índices bioclimáticos e produtivos em diferentes galpões avícolas no semiárido paraibano. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 14, n.12, p. 1330-1336, 2010.

SANTOS, G. B.; SOUSA, I. F.; BRITO, C. O.; SANTOS, V. S.; BARBOSA, R. J.; SOARES, C. Estudo bioclimático das regiões litorânea, agreste e semiárida do estado de Sergipe para avicultura de corte e postura. **Ciência Rural,** Santa Maria, v. 44, n.1, p. 123-128, 2014.

SOUZA, M. S.; TINÔCO, I. F. F.; AMARAL, A. G.; INOUE, K. R. A.; BARRETO, L. S.; SAVASTANO JUNIOR, H.; SOUZA, C. F.; PAULA, M. O. Thermal comfort zones for starter meat-type qualis. **Brazilian Journal of Poultry Science**, Campinas, v. 16, n.3, p. 265-272, 2014.

VIGODERIS, R. B.; CORDEIRO, M. B.; TINÔCO, I. F. F.; MENEGALI, I.; SOUZA JUNIOR, J. P.; HOLANDA, M. C. R. Avaliação do uso de ventilação mínima em galpões avícola e sua influência no desempenho de aves de corte no período de inverno. **Revista Brasileira de Zootecnia**, Viçosa, MG, v. 39, n. 6, p. 1381-1386, 2010.