revista engenharia agrícola
Journal of the Brazilian Association of Agricultural Engineering
ISSN: 1809-4430 (on-line)

ENVIRONMENT IN POULTRY PRODUCTION COVERED WITH THERMAL AND ALUMINUM ROOFING TILES

Doi:http://dx.doi.org/10.1590/1809-4430-Eng.Agríc.v35n2p206-214/2015

FERNANDO G. DE OLIVEIRA[1], WANESSA M. GODOI [2], ROBERTA PASSINI [3]

ABSTRACT: Brazil is a country of tropical climate, a fact that hinders the poultry production in the aspect of thermal comfort. Thus, we aimed to evaluate the thermal environment in commercial poultry houses with different covers during the months of December 2012 to May 2013, in the municipality of Rio Verde, Goiás. The experimental design was completely randomized in split plots with factorial arrangement of treatments 2x3, being two shed models (thermal and aluminum roof tiles) and three sections within each shed (initial, central and final) for 182 days, having the days as replicates. The thermal environment was assessed through thermal comfort indices: Temperature and Humidity Index, Black Globe Temperature and Humidity Index, Radiant Heat Load and Enthalpy. The data was analyzed by SISVAR 5.1., through the analysis of variance, the Scott Knott test used to compare the means, considering a significance level of 1%. The results showed a significant statistical difference between the sheds and the points assessed ($P < 0.05$). The thermal shed had the lowest values for the environmental variables (Dbt and Bgt) and thermal indices studied, but larger values for the RH compared to the shed with aluminum covering. The use of thermal covers minimizes the difference in temperature range throughout various times of the day, being at 14:00 o'clock the prominence time to others.

KEYWORDS: thermal environment, bioclimatic indices, roofs.

AMBIÊNCIA EM AVIÁRIOS MATRIZEIROS COBERTOS COM TELHAS TÉRMICAS E DE ALUMÍNIO

RESUMO: O Brasil é um país de clima tropical, fato que dificulta a produção de aves no aspecto de conforto térmico. Desta forma, objetivou-se avaliar o ambiente térmico, em três seções de galpões avícolas matrizeiros comerciais com diferentes coberturas, durante os meses de dezembro/2012 a maio/2013, no município de Rio Verde, Goiás. O delineamento experimental foi o inteiramente casualizado, em parcelas subdivididas, com arranjo fatorial de 2x3, sendo dois modelos de galpões (telhas térmicas e telhas de alumínio) e três seções avaliadas dentro de cada galpão (inicial, central e final), durante 182 dias, tendo os dias como repetições. O ambiente térmico foi avaliado através de índices de conforto térmico: Índice de Temperatura e Umidade, Índice de Temperatura Globo Negro e Umidade, Carga Térmica Radiante e Entalpia. Os dados foram analisados pelo programa SisVar 5.1., por meio da análise de variância, sendo o teste de Scott Knott, a 1% de significância. Os resultados mostram que houve diferença estatística entre as variáveis ambientais e os índices de conforto térmico aferidos nos diferentes galpões, e também, entre as seções avaliadas ($P<0,05$). O galpão térmico apresentou os valores menores para as variáveis ambientais (Tbs e Tgn) e para os índices térmicos estudados; porém, maiores valores para a UR, em comparação ao galpão com cobertura de alumínio. O uso de coberturas térmicas minimiza a diferença de amplitude térmica ao longo dos diversos horários do dia, tendo o horário das 14 horas se destacado perante os outros.

PALAVRAS-CHAVE: ambiente térmico, índices bioclimáticos, telhados.

[1] Engº Civil, Mestre, Departamento de Engenharia Agrícola, UEG/Anápolis – GO, Fone: (62) 3328-1156, fernando@isoeste.com.br
[2] Engº Agrícola, Mestranda, Departamento de Engenharia Civil, UFG /Goiânia – GO, Fone: (62) 8139-2028, wanessa.m.godoil@gmail.com
[3] Veterinária, Profa. Pós-Doutorada, Departamento de Engenharia Agrícola, UEG/Anápolis – GO, Fone: (62) 3328-1156, rpassini@ueg.br
Recebido pelo Conselho Editorial em: 10-6-2014
Aprovado pelo Conselho Editorial em: 14-10-2014

INTRODUCTION

The poultry industry in Brazil has great importance in the international and domestic market, highlighted the strong productive and commercial dynamism of poultry production which employs more than 3.6 million people directly and indirectly, and accounts for nearly 1.5% of the Gross Domestic Product (GDP). In this context producing farms matrices has the key role for supply eggs to hatcheries, and these for broilers farms (UBABEF, 2013).

According to the annual report of Brazilian Poultry Union for 2013, the chicken meat production reached 12.645 million tons in 2012, in a reduction of 3.17% from 2011. Brazil retained the position of world's largest exporter and third largest poultry meat producer, behind the United States and China.Of the total volume of chickens produced by the country 69% was destined for internal consumption and 31% for exports. The per capita consumption of chicken has reached 45 kg per person. Shipments of 3.918 million tons in 2012 represented a decrease of 0.6% compared to 2011.

According to ABREU & ABREU (2011), the aviaries implanted in Brazil have strong influence on existing industry equipment in temperate countries (USA and Europe). This fact without the necessary adjustments to the bioclimatic local results in installations that generate thermal discomfort, increased incidence of diseases linked to loss of air quality and energy dependence.

Despite of the poultry farming growth it turns out that, in tropical and subtropical climates, as occurs in Brazil, the high values of air temperature and relative humidity, especially in the summer, generate thermal discomfort condition almost permanent for poultry, hindering their productive performance and constituting one of the main problems that affect its. As a strategy to suit the thermal environment inside the sheds to the requirement of thermal comfort of the birds, the climate control is an efficient output according to MACHADO et al. (2012).

The animal comfort was seen as a secondary issue, however in the last decades the concern with animal comfort is increasing noticeably, especially when associated with physiological responses as indicators of it (SILVA, 2010).Yet there's still lack of investigations about the welfare for the architectural and constructive conditions of Brazilian poultry sheds (CORDEIRO et al., 2010).

According to FERREIRA (2005) the ambient temperature indicated for layers and matrices should vary between 15 to 28°C. In the first days of life the temperature must be between 33 to 34°C, depending on the relative humidity which can range from 40 to 80%. SALGADO & NÄÄS (2010) claim that the thermal environment influences the growth performance, being one of the main responsible for losses in productive tropical climate regions which are potentially of high magnitude because they cover direct and indirect losses.

SAMPAIO et al. (2011) reported that the temperature variations in non-shaded areas tend to follow the local climate while inside the sheds there is a milder thermal behavior in the course of the day since the coverage eases the variation temperature and doesn't let the thermal fluctuation occurs more abruptly. For NÄÄS et al. (2001) the roof is the most significant constructive element in a poultry shed regarding to the control of the incident solar radiation.

With respect to the effect of temperature on laying hens several studies show the existence of a thermal comfort zone in which the animal is. However the determination of the thermal comfort zone involves the knowledge and the interactions of many variables that can influence this process (moisture, management, ventilation, sheds, etc). Currently studies are carried out in order to reduce the caloric stress. However there is a need to link the environment to the genetic potential of the layers (SILVA et al. 2010), besides the need to evaluate different roof materials and thermal packaging systems (BAÊTA & SOUZA, 2010).

This research was conducted to assess the thermal environment by means of thermal comfort index THI, BGHI and RHL in commercial matrices poultry sheds with different roofing on timetables at 8:00, 10:00, 12:00, 14:00, 16:00, 18:00 and 20:00.

MATERIAL AND METHODS

The experiment was conducted in commercial sheds for matrices EPS (Egg Production System) as part of the integration system BRF-Granja Ipê, located in the municipality of Rio Verde, Goias situated in geographical coordinates 17° 32 ' 53 "S and 50° 54 ' 53" W, atmospheric pressure of 101600 Pa. The climate classification according to KÖEPPEN is of type Aw, tropical rainy with dry winter. In the period were recorded maximum and minimum external temperatures of 46.7° C and 13.6° C, minimum and average humidity of 25% and 85% respectively, maximum winds of 12.2 Km/h and an accumulated rainfall of 1.196 mm.

The sheds for matrices have technical dimensions of 224.30 m long and 12.30 m wide and ceiling height of 2.54 m divided into four symmetrical boxes of 110 m long x 6.15 m wide with a capacity for 12.333 females birds and 1.333 male birds per shed with a nucleus composed of three sheds. In the experiment were used only two sheds being the shed with thermal roof located at the coordinate 17° 33 ' 66 ' S and 50° 43 ' 21 ' W at an altitude of 698 m and the shed with aluminum roof in coordinate 17° 35 ' 06 'S and 50° 42 ' 47 ' W at an altitude of 627 m separated from each other by a distance of 2,400 meters.

The sheds are equipped with artificial ventilation system by exhaustion and evaporative system in the same quantities and dimensions, specified below, holed brick masonry and side low walls of 0.30 m, concrete floor with rice straw bed, wire mesh to side locking, plastic canvas side automated curtains; four lines of automatic feeders with two lines of nipple type drinkers, a line of automated nests which housed 6,166 female birds and 666 males birds .

The climate control system was composed of ventilation in tunnel (negative pressure) with seven exhaust fans, BF 50 type of 1,5 CV, situated in the back of the shed, and evaporative cooling system of moistened porous material type *(pad cooling*): containing 02 cellulose plates of 8.5 m long and 1.84 m high, allocated at the initial region of the shed, being the largest located in the east-west direction. The surrounding vegetation was constituted of the eucalyptus species trees, acting as windbreaks. In the two sheds used in the experiment we worked only on half of its length, i.e. 110 m x 12.30 m each being this physical division of the own edification.

For the analysis of data on environmental variables and indexes of thermal comfort was used a completely randomized design, on plots subdivided, with a factorial arrangement 2 x 3 treatments, being two sheds (thermal roof and aluminum roof) and three points or sections within each shed (initial, central and final), during 182 days as repetitions.

The sheds were evaluated:

Thermal roof: composite sandwich Galvalume steel ® CSN type and insulating core in EPS (expanded polystyrene) with minimum thickness of 30 mm, with thermal characteristics of 0.033 W/m. K (ISOESTE ®);

Aluminum roof: natural aluminum TP40 trapezoidal type# 0.50 mm, without thermal insulation, with thermal characteristics 218 W/m. K (ALCOA ®).

Sections or points assessed were:

Initial: thermal sensors were positioned in the initial portion of the shed (where were located evaporative plates), the axis region at 0.60 m of height from the nest base;

Central: on the central portion of the shed, the axis at 0.60 m of height from the nest base and at 1.20 m from the floor because in this part of the shed we have a discontinuity of nests;

Final: on the final parcel of the shed (where the exhaust fans are located), the central line at 0,60 m height of the nest base.

The data were collected during the months of December 2012 to May 2013, totalizing a period of six months, collecting environmental variables every 10 minutes.

The climate data were collected with the aid of Data Loggers in the two experimental sheds, with 110 m long x 12.30 m wide, and at three points within each shed. Collect sensors were distributed in the central axis with 27.5 m distance between them being the initial and final at a height of 0.6 m from the nest base and the central at a height of 1,20 m of the floor level, collecting environmental variables every 10 minutes.

Each collect point was composed by the equipments: Data Logger H21-002, humidity and temperature Sensor (S-THB-M002), air temperature Sensor with wet bulb (S-TMB-M002-wet bulb), Temperature Sensor with black globe (S-TMB-M002), direction Sensor and wind speed (S-WSA-M003) and solar radiation Sensor (S-LIB-M003).Registry sensors feature precision of ± 0.2 ºC to air temperature and ± 2.5% for RH . The anemometer had accuracy of 0.5 m/s and the solar radiation was measured by resolution sensor of 1.25 W/m².

A portable meteorological station was installed in the region around the sheds for the collect of climate variables of the external environment.

From the data of Dbt (dry bulb temperature), Wbt (wet bulb temperature), Bgt (black globe temperature) and W (wind speed), the thermal comfort indexes THI (temperature and humidity index by Thom, 1959), BGHI (globe temperature and humidity index, according to Buffington et al. (1981), RHL (Radiant Heat Load, according Esmay (1969), and H (enthalpy), according to the following eq. of (1) to (5).

$$THI = Dbt + (0.36.Dpt) + 41.5 \tag{1}$$

where,

Dbt = dry bulb temperature (° C);

Dpt = dew point temperature (° C).

$$BGHI = Bgt + 0.36.Dpt - 330.08 \tag{2}$$

where,

Bgt = black globe temperature, K;

Dpt = dew point temperature, K.

$$RHL = \sigma(ART)^4 \tag{3}$$

where,

σ = Stefan-Boltzmann constant (5.67 x 10-8 W m^{-2} K^{-4});

ART = average radiant temperature.

$$ART = 100\left[2.51\sqrt{AS}\,(Bgt - Dgt) + \left(\frac{Bgt}{100}\right)^4\right]^{\frac{1}{4}} \tag{4}$$

where,

AS= air speed, m/s;

Dbt = dry bulb temperature, K.

$$H = 6.7 + 0.243.Dbt + \left\{\frac{RH}{100}.10^{\frac{7.5Dbt}{237.3+Dbt}}\right\} \tag{5}$$

where,

Dbt = dry bulb temperature (° C);

RH = relative humidity, %.

BHW–PRO from ONSET® software was used for compilation of collected data by registers for comparative analysis of thermal comfort indexes at different times.

The data were subjected to analysis of variance, assuming the existence of variance homogeneity and residual normality, using the computer program SISVAR 5.3® (FERREIRA, 2010).When averages were significant, they were compared by Scott-Knott test adopting a level of significance of 1% for climate data and comfort indexes.

RESULTS AND DISCUSSION

Significant statistical differences were observed between the sheds evaluated ($P < 0.05$) for thermal comfort indexes (THI, BGHI, RHL and H), as shown in Table 1.

TABLE 1. Averages of THI (Temperature and Humidity Index), BGHI (Black Globe Temperature and Humidity Index) and RHL (Radiant Heat Load) and enthalpy (H) in the sheds with thermal tile and aluminum tile, with respective coefficients of variation and statistical probability.

Causes of variation		**THI**	**BGHI**	**RHL (W/m²)**	**H (KJ/Kg)**
		Main effects *			
Shed	Thermal	74.00a	74.72a	448.94a	17.11a
	Aluminum	75.42b	75.74b	455.75b	17.49b
Start Point		74.71a	75.12a	451.69a	17.33b
Center point		74.91b	75.17a	451.37a	17.44b
Final Point		74.52a	75.41a	453.97b	17.13a
		Interactions **			
Thermal	Start Point	74.43b	74.89b	449.62b	17.33b
	Center Point	74.07b	74.24a	446.18a	17.19b
	Final Point	73.50a	75.04b	451.01b	16.80a
Aluminum	Start Point	74.98a	75.35a	453.75a	17.33a
	Center Point	75.75b	76.09b	456.57b	17.69b
	Final Point	75.53b	75.79b	456.92b	17.46a
		Statistic Probability			
Shed		0.0001	0.0001	0.0001	0.0001
Points		0.0227	0.0872	0.0001	0.0001
Shed x Points		0.0001	0.0001	0.0001	0.0001
Medium		74.71	75.23	452.34	17.30
C.V. (%)		2.57	2.58	1.89	4.28

* In the main effects, lowercase letters differ within the columns differ statistically by Scott-Knott test, 1% probability.

* * The interactions, lowercase letters differ within the columns differ statistically by Scott-Knott test, 1% probability, representing the effect of points within each shed.

The THI differed between the sheds being the lowest in the shed with thermal roof (74.00) comparing to the conventional aluminum-roof shed (75.42), presented a greater value in central point in relation to others. ARMSTRONG (1994) classified the thermal stress according to the variation of THI in mild (72 to 78), moderate (79 to 88) and severe (89 to 98), whereby a THI below 72 characterize a stress-free heat environment. Thus, in this study, in both treatments, we can classify as mild THI.

The BGHI showed the same pattern of THI, presenting lower values for the thermal shed (74.72) compared to conventional (75.74), however it showed no significant difference between the assessed points. MEDEIROS (2005) considers BGHI of 58 to 67 characteristic of cold environments and BGHI of 78 to 88 of hot environments, being the BGHI of 68 to 77 considered comfortable for birds, in this band where the BGHI values were found for this study. BAÊTA & SHARMA (2010); FERREIRA (2005); SANTOS (2008) described that the BGHI inside the sheds until 74 is considered safe and between 74 and 78 requires special care.

MORAES (1999), tested different types of roofing with Black globe thermometer positioned at the height of the shed ceiling and at the birds' high it was showed differences in RHL values in the West of Parana in the months of May, July and August. This author found average value of RHL equal to 465.29W / m² for level of birds and RHL of 475.24W / m², values higher than those found in this experiment that can be explained by the period and different climate of each region.

Regarding the differences between the studied points, it can be seen that based on the RHL values, initial and central points are lower in this index compared to the final of the shed which suggests the efficiency use of the evaporative plate in order to promote the improvement of the thermal environment.

According to Table 1, similar behavior to that observed with the environmental variables; there was an interaction between treatments (P <0.01), so that the thermal shed had lower amplitudes of temperature variations along its length in relation to the aluminum roof shed in which it was observed increasing in the rates of thermal comfort THI, BGHI and RHL for the central and final points of the shed. Only the enthalpy that presented values that did not differ between the starting and final points in conventional shed. However, the enthalpy values found in the shed were lower and the lowest value was observed at the final point of the shed.

According to BARBOSA FILHO et al. (2006), for broiler chicken, enthalpy values over 70 kJ/kg of dry air are considered as high enthalpy and in this way we can say that no treatment has been close to the value in the present study where it was observed H values of 17.30 kJ/kg of dry air in average.

Significant statistical differences were observed between the sheds during the hours of the day measured (P < 0.05), both for the environmental variables (Bgt, Dbt and RH), as for the thermal comfort indexes (THI, BGHI, RHL and H), as shown in Table 2.

For the black globe temperature, there was difference between the treatments, except for 8 h and 20h.In other times of the day, the shed with thermal roofs presented values of Bgt below the shed covered with aluminum tiles. DAMASCENO et al. (2010), when evaluating two poultry sheds with evaporative cooling in different type of porous board systems reported that the differences between cooling system are sharper in the hot period, however it was not observed this distinction of values in other periods of the day.

For dry bulb temperature the differentiation between sheds happened at all times, and the shed with thermal roofing presented throughout the day, the lowest values and at 14 h had the peaks' temperature.

Relative humidity presented contrary to the behavior of the Bgt and Dbt, in which at temperature peak hours were the time that occurred the smallest values of RH, again at 14 h. However, the shed with thermal roofs presented higher values of RH than the conventional, that can be justified on the used materials in the treatments, given the significant differences in thermal conductivity coefficients, where a material passes more energy from one medium to another, ROCHA et al. (2010) studying sheds covered with ceramic roofs or cement in the State of Paraiba, did not observed differences between the sheds for temperature and relative humidity, black globe temperature and humidity index, radiant heat load and the speed of wind, but at the hottest time of the day (10h to 16h), the authors found mean values above the comfort zone, causing uncomfortable situation for the birds.

TABLE 2. Interaction of sheds with thermal cover and sheds with aluminum cover between the hours of the days to (°C), Dry Bulb Temperature (°C), Relative Humidity (%),Temperature and Humidity Index, Black Globe Temperature and Humidity Index, Radiant Heat Load (Wm^{-2}) and Enthalpy (kJ/kg).

Treatments	Timetable						
	8h	**10h**	**12h**	**14h**	**16h**	**18h**	**20h**
Black Globe Temperature (ºC)							
Thermal	23.49A	26.27A	27.36A	27.75A	27.09A	26.76A	25.56A
Aluminum	23.84A	27.46B	29.97B	30.42B	29.37B	27.97B	26.11A
Dry Bulb Temperature (ºC)							
Thermal	22.90A	25.29A	26.21A	26.49A	25.92A	25.78A	24.74A
Aluminum	23.48B	26.98B	29.54B	29.94B	28.87B	27.38B	25.59B
Relative Humidity (%)							
Thermal	95.17B	89.12B	87.69B	86.21B	86.91B	85.86B	89.00B
Aluminum	90.28A	80.61A	74.61A	72.80A	75.22A	78.47A	84.25A
Temperature and Humidity Index							
Thermal	72.44A	75.37A	76.55A	76.84A	76.09A	75.80A	74.57A
Aluminum	72.82A	76.86B	79.84B	80.14B	78.97B	77.23B	75.25B
Black Globe Temperature and Humidity Index							
Thermal	72.93A	76.25A	77.61A	78.00A	77.16A	76.69A	75.29A
Aluminum	73.08A	77.24B	80.17B	80.53B	79.37B	77.72B	75.68A
Radiant Heat Load (Wm^{-2})							
Thermal	439.33A	456.61A	463.81A	466.24A	461.86A	459.30A	451.61A
Aluminum	441.29A	463.35B	479.19B	482.16B	475.8B	466.51B	454.92A
Enthalpy (kJ/kg)							
Thermal	16.64A	17.56A	17.97A	18.03A	17.76A	17.63A	17.26A
Aluminum	16.70A	17.97B	18.92B	18.99B	18.59B	18.02B	17.44A

Different capital letters, inside of the columns differ statistically by Scott-Knott test, 1% probability.

For the THI there was difference between the sheds during the hours of the day, except at 8 h and at 14h that was the time of the greatest index, been the conventional shed treatment the one presenting the highest values.

The BGHI followed the same trend of the THI, however it did not report difference at 8 h and also did not differ at 20 h. At 14h, it stood out with the highest temperatures and the thermal shed with the lowest values compared to the shed covered with aluminum roofing. According to NÄÄS et al (2001), in experiments with small-scale models, the BGHI values were found at 14h and were also higher than those recommended. FURTADO et al. (2003) in a study of different heat-treatment systems for poultry sheds found values of BGHI around 80. The same authors report that a significant portion of overheating is from the own heat generated by the birds, which aggravates the situation of thermal discomfort inside the sheds, especially in the hottest hours of the day. The RHL presented similar behavior to other indexes, differed throughout the day, with lower values observed in the thermal shed compared to conventional, except for the time at 8h and 20h, presented at 14h a difference of 16Wm^{2} less to the thermal shed. FURTADO et al. (2003) analyzed, in the wild of the State of Paraiba, the thermal comfort of poultry sheds with different packaging systems and found at 14h values for RHL of 505.31 Wm^{-2} for the ceramic roof without artificial ventilation, values higher than those observed in this study. Similarly, the study done by ROSA (1984) obtained at 14h in clear typical sky day, RHL values of 498.3 Wm^{-2}, 515.0 W m^{-2} and 498.0 W m^{-2} under French type clay roof, asbestos cement, and aluminum, respectively.

MORAES et al. (1999) performed studies on models of sheds with asbestos cement roof and found BGHI values between 75.5 to 83.2 in the hottest hours and RHL between 455.2 W m^{-2} and 504.0 W m^{-2}. Again, these values are higher than those found in this experiment.

In contrast CONCEIÇÃO et al. (2008) compared conventional and other roofs, in poultry sheds prototypes for summer conditions, and found the following average values for asbestos cement roofs painted with reflective paint and ceramic roofs, respectively: THI (71.9 and 72.3), BGHI (71.9 and 73.7), RHL (449.17 W m^{-2} and 477.74 W m^{-2}), these values are close to those found in this study.

CONCLUSIONS

The shed with thermal coverage presented more favorable values as for thermal comfort indices THI, BGHI and RHL, in relation to the shed covered with aluminum tiles. The use of thermal covers minimizes thermal amplitude difference, between the different sections within the poultry sheds, and even over the various times of the day. At 14h, it presented the highest values in the various sheds for all the environmental variables and indices of thermal comfort, and may be considered the critical hour.

REFERENCES

ABREU, V.M.N.; ABREU, P.G. Os desafios da ambiência sobre os sistemas de aves no Brasil. *Revista Brasileira de Zootecnia*, Viçosa, MG, v.40, p.1-14, 2011.

ARMSTRONG, D. V. Heat stress interation with shade and cooling. *Journal of Dairy Science*, Savoy, v.77, p. 2044-2050, 1994.

BAÊTA, F. C.; SOUZA, C. F. *Ambiência em edificações rurais*: conforto animal. Viçosa: EDUFV, 2010. 269p.

BARBOSA FILHO, J. A. D.; SILVA, M. A. N.; SILVA, I. J. O.; COELHO, A. A. D. Egg quality in layers housed in different production systems and submitted to two environmental conditions. *Brazilian Journal of Poultry Science*, Campinas, v.8, n.1, p.23-28, 2006.

BUFFINGTON, D. E.; COLAZZO-AROCHO, A.; CANTON, G. H.; PITT, D. Black globe-humidity index (BGHI) as comfort equation for dairy cows. *Transaction of the ASAE*, St. Joseph, v.24, p.711-714, 1981.

CONCEIÇÃO, M. N.; ALVES, S. P.; TELATIN, A. J.; SILVA, I. J. O.; PIEDADE, S. M. S.; SAVASTANO, H. J.; TOLONI, G. Desempenho de telhas de escória de alto forno e fibras vegetais em protótipos de galpões. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.12, n.5, p. 536-539, 2008. Disponível em: <http://dx.doi.org/10.1590/S1415436620080005000015>. Acesso em: 10 set. 2013.

CORDEIRO, M. B.; TINOCO, 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.

DAMASCENO, F. A. JUNIOR, T.Y.; LIMA, R.R. de; GOMES, R.C.C.; MORAES, S.R.P. de. Avaliação do bem-estar de frangos de corte em dois galpões comerciais climatizados. *Ciência e Agrotecnologia*, Lavras, v.34, p.1031-1038, jul./ago. 2010.

ESMAY, M. L. *Principles of animal environment*. Environmental Engineering in Agriculture and Food Series. Westport: The AVI Publishing Company, 1969. 325 p.

FERREIRA, R.A. *Maior produção com melhor ambiente para aves, suínos e bovinos*. Viçosa: Aprenda Fácil, 2005. 371p.

FERREIRA, D. F. *SISVAR* - Sistema de análise de variância. Versão 5.3. Lavras: UFLA, 2010.

FURTADO, D. A.; NASCIMENTO, J.W.B.; AZEVEDO, P.V. Análise do conforto ambiental em galpões avícolas utilizando telhas de barro e suas associações no agreste paraibano. *Revista Brasileira de Ciência Avícola*, Campinas, n.5, p. 107, 2003.

MACHADO, N. S.; TINÔCO, I. D. F. F.; ZOLNIER, S.; MOGAMI, C. A.; DAMASCENO, F. A.; ZEVIANI, W. M. Resfriamento da cobertura de aviários e seus efeitos na mortalidade e nos índices de conforto térmico. *Nucleus*, La Habana, v. 9 n. 2, 2012.

MEDEIROS, C.M.; BAÊTA, F.C.; OLIVEIRA, R.F.M.; TINÔCO, I.F.F.; ALBINO, L.F.T.; ECON, P. Índice térmico ambiental de produtividade para frangos de corte. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.9, n.4, p.660-665, 2005.

MORAES, P.R.S.; TINOCO, F.F.I.; BAETA, C.F.; CECON, R.P. Conforto térmico em galpões avícolas, sob coberturas de cimento-amianto e suas diferentes associações. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.3, n.1, p.89-92, 1999.

MORAES, S.R.P. *Conforto térmico em modelos reduzidos de galpões avícolas, para diferentes coberturas, durante o verão*. 1999. 73f. Dissertação (Mestrado em Engenharia Agrícola) – Universidade Federal de Viçosa, Viçosa, 1999.

NÄÄS, I.A.; SEVEGNANI, K. B.; MARCHETO, F. G.; ESPELHO, J. C. C.; MENEGASSI, V.; SILVA, I. J. O. Avaliação térmica de telhas de composição de celulose e betumem, pintadas de branco, em modelos de aviários com escala reduzida. *Engenharia Agrícola*, Jaboticabal, v.21, n.2, p.121-126, 2001.

ROCHA, H. P.; FURTADO, D. A.; NASCIMENTO, J. W. B. do; 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, p.1330-1336, 2010.

ROSA, Y.B.C.J. *Influência de três materiais de cobertura no índice de conforto térmico em condições de verão*. 1984. 77f. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Viçosa, Viçosa, 1984.

SALGADO, D.D.; NÄÄS, I.A. Avaliação de risco à produção de frango de corte do estado de São Paulo em função da temperatura ambiente. *Engenharia Agrícola*, Jaboticabal, v.30, n.3, p.367-376, 2010.

SAMPAIO, C. A. P.; CARDOSO, C. O.; SOUZA, G. P. Temperaturas Superficiais de Telhas e sua Relação com o Ambiente Térmico. *Engenharia Agrícola*, Jaboticabal, v.31, n.2, p. 230 - 236, mar./abr. 2011

SANTOS, P. A. dos. *Qualidade do ar, conforto térmico e desempenho de frangos de corte em dois sistemas de aquecimento e ventilação*. 2008. 126f. Tese (Doutorado em Engenharia Agrícola) – Departamento de Engenharia Agrícola. Universidade Federal de Viçosa, Viçosa, 2008.

SILVA, E.N. *Tifo aviário em alerta vermelho*. 2010. Disponível em: <http://pt.engormix.com/MA-avicultura/saude/artigos/tifo-aviario-alerta-vermelho t292/165-p0.htm>. Acesso em: 20 set. 2013.

SILVA, R. G. *Introdução à bioclimatologia animal*. São Paulo: Nobel, 2000. 286 p.

THOM, E. C. The discomfort index. *Weatherwise*, Washington, v.12, n.1,p.57-60, 1959.

UBABEF. *União Brasileira de Avicultura, Relatório anual 2013*. Disponível em: <http://www.ubabef.com.br/publicacoes>. Acesso em: 2 out. 2013.