Climate Change Influence on Inside Thermal Environment of Broiler Houses

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Abstract. *Climate change may substantially affect animal production. General circulation models (GCM's) have shown the trend of increasing air temperature in several parts of South America. Therefore, the goal of this work was to evaluate the influence of climate change on the inside thermal environment of broiler housings through simulation. In this study, mean air temperatures (t_{mean}) and air relative humidity (RH) acquired in Lavras – MG - Brazil, from 1975 to 2005, totaling 30 years were used. The air velocity used to simulation inside the broiler houses was 2.0 m s-1. These data were used as input in a mathematical model to predict the black-globe humidity index (BGHI) inside of poultry housings. Simulated results suggest the need of changing ventilation and cooling strategies and increase of structure thermal resistance to minimize the weather effects on the thermal environment inside of broiler housing.*

Keyword. *Poultry, Global warming, Thermal environment, Simulation*

Introduction

The Brazilian broiler chicken has been highlighted in the national and international scenario, mainly due to technology to aggregate production process. Factors such as globalization, increased competition, demands for products of better quality and more healthy, among others, have done farmers search in researches, technologies to achieve higher productivity with lower costs, considering the chicken's welfare. Thus, to obtain the maximum productivity is essential to have an breeding stock with high genetic potential, adequately fed, created in aseptic environment and thermally adjusted to the needs of chickens.

The possibility of climate change, especially in the regime of temperature and precipitation, is often singled out as cause of the interference of man in the environment especially by thinning (Serra Filho et al., 1975) and by urbanization (Karl et al., 1988), making this an environmental problem rather complex and brings possibly catastrophic consequences.

Several global climate changes occurred throughout evolutionary planetary history inducing new conditions of balance. Studies have shown the relationship between the atmospheric warming, global climate changes and its effects on the ecosystems distribution, leading to profound changes in the current biodiversity composition (Salati et al., 2001).

In the twentieth century, there was an increase of 0.65°C in the average global temperature, which is more pronounced in the 90^{th} decade. As for precipitation, the increase ranged from 0.2% to 0.3% in the tropical region, between 10° North and 10° South of latitude. The causes of these variations may be natural or anthropogenic, or both (IPCC, 2001). Through mathematical models based on data recorded from oceans, atmosphere and biosphere, is foreseen an increase by 1.4°C and 5.8°C in global average temperature by the end of the XXI century (IPCC, 2001).

Based on the problem exposed, the aim of this research is to study the effect of variables and their possible climatic current projections for the years 2020, 2050 and 2080 under the influence of change in the weather, and two types of cover materials (ceramics and sandwich) in the internal environment of conventional broiler housings, through the computer simulation of the black-globe humidity index (BGHI).

Material and Methods

To review the current situation and future of the climate in Lavras city -MG, and verify their effects on the internal environment of conventional broiler housings, it was used climatic data measured in the Lavras city-MG, and a mathematical model for predicting the BGHI inside of poultry housings, developed by Oliveira (1980) and adapted by Yanagi Junior et al. (2001). The computer program used for the simulation was developed by Severo et al. (2003).

Data Weather

Data from daily average temperature (t_{mean}) and relative humidity (RH), which covered the period from 1975 to 2005 were used, totaling 30 years. These data were measured at the primary climatologic station from Lavras city, belonging to the national network of meteorological observations of the Institute of

Meteorology (INMET). This station is located in the campus of the Federal University of Lavras (latitude: 21 ° 14 ', Longitude: 45 ° 00' e altitude: 918.84 m), and agreement between UFLA and INMET.

Mathematical and Computational Model

The simulations of BGHI inside conventional warehouses for broiler chickens creation were made using the mathematical model proposed by Oliveira (1980) and adapted by Yanagi Junior et al. (2001), in which the main equations are used to calculate the mean radiant temperature, the radiant load (RHL) from direct and diffuse radiation incident on inclined surfaces and BGHI (Equation 1).

$$BGHI = T_{bg} + 0.36\ T_{dp} - 330.08 \qquad (1)$$

The black globe temperature (T_{gn}) can be determined by the equation of the radiant energy average (T_m), obtained through the balance on the globe surface, where the heat gained or lost by radiation in the surround should be equal to heat gained or lost by convection, being calculated as expressed in the Equation 2 (Esmay,1986):

$$T_m = 100.\left[2.51.\sqrt{v}.\left(T_{bg} - T_{db}\right) + \left(\frac{T_{bg}}{100}\right)^4\right]^{\frac{1}{4}} \qquad (2)$$

The radiant energy of the environment can be defined according to the Stefan-Boltzmann law after rearrange that can be expressed as Equation 3:

$$T_m = \left(\frac{RHL}{\sigma}\right)^{\frac{1}{4}} \qquad (3)$$

As proposed by Kelly et al. (1954), the RHL express the flux of radiation incident on the black globe from different regions around the globe (lower roof surface, cold sky, horizon, shaded ground and unshaded ground). Thus, the RHL depends on the materials used in construction, been calculated by the Equation 4:

$$RHL = \sigma.\sum_{i=1}^{n} T_i^4.F_i \qquad (4)$$

Yanagi Junior et al. (2001) adapted the mathematical model developed by Oliveira (1980) and validated it. The values of BGHI were observed and predicted with the model of 10^{th} to 49^{th} day of broiler aging at 8:00, 10:00, 12:00, 14:00 and 16:00 hours. The data corresponding to the first ten days were rejected due to the influence of the operation of heaters in the center of the building on the black globe temperature measurements. For the period considered could be verified that the estimated values of BGHI adjusted very well with those observed with standard deviations of 0.99, 0.99, 1.37, 0.99, 1.25 to 8:00, 10:00, 12:00, 14:00 and 16:00 hours, respectively. The lowest coefficient of determination (r^2) found was 0.88 at 12:00 hours and the highest was 0.94 for the range from 14:00 to 16:00 hours. To 8:00 and 12:00 hours the values were 0.91 and 0.93, respectively. The average total error was 1.31%.

Simulations

For the characterization of the current situation were considered the daily average temperature and relative humidity of the past 30 years. For the simulation of future projections for the years 2020, 2050 and 2080 increases in the current temperature data were adopted, respectively, 2°C, 3°C and 5°C following the projections of reports on climate change (IPCC, 2001; Hegerl et al., 2007).

The simulations were performed to two broiler housings, east-west oriented, with dimensions of 12 m wide, 120 m long and 3.0 m column height. The first has French-type ceramic gable roof with 25° sloop and shingles thickness of 0.025 m, thermal conductivity of 0.40 $W.m^{-1}.K^{-1}$, absorptivity coefficient of 0.85, and other has sandwich-type gable roof with 5,7 ° of sloop and thickness of 0.05 m, thermal conductivity of 0,0314 W/m·K and absorptivity coefficient of 0.6. Convective heat transfer on the external surface of the roof was 22.4 W/m·K in agreement with Teixeira (1983).

Shape factors for each facility were calculated and assumed the following values: a) French-type ceramic gable roof: 0.016 for unshaded floor, 0.484 for shaded floor, 0.087 for horizon, 0.02 for cold sky and 0.411 for roof, and b) sandwich-type gable roof: 0.016 for unshaded floor, 0.484 for shaded floor, 0.087 for horizon, 0.04 for cold sky and 0.373 for roof. Shape factors were calculated through the methodology proposed by Kelly et al. (1954). Dimensionless dust parameter of 0.41were assumed (Alves, 1981).

Statistical Analysis

BGHI inside of broiler houses equipped with ceramics and *sandwich* tiles for air velocity of 0.2 m/s were compared through t-test using the routine PROC TTEST from SAS® (SAS, 2001).

Results and Discussion

Table 1 shows the difference between BGHI values found for the four climatic situations studied: current (mean of years 1975 to 2005) and 2020, 2050, 2080 years, simulated for the two treatments, ceramic and sandwich tiles, being statistically different (t Test, $P < 0.01$). It is observed in the facility equipped with ceramic tile that, with the influence of global warming on year's average temperatures, the tendency of BGHI presents significant increase, affecting the thermal comfort temperature of broiler chickens. BGHI profile in facilities equipped with sandwich tiles has the same profile of the ones equipped with ceramic tiles, however with lower values.

Table 1. Difference between black-globe humidity index (BGHI) values calculated between treatments on the basis of daily average values of temperature of the past 30 years (1975 - 2005) for the current situation and for future projections for the years 2020, 2050, 2080, Lavras city, MG.

		Ceramic tile Time (Year)				Sandwich tile Time (Years)			
		Present	2020	2050	2080	Present	2020	2050	2080
Ceramic tile	Present	-	-	-	-	-	-	-	-
	2020	2.69*	-	-	-	-	-	-	-
	2050	4.03*	1.35*	-	-	-	-	-	-
	2080	6.73*	4.03*	2.69*	-	-	-	-	-
Sandwich tile	Present	1.42*	4.11*	5.46*	8.15*	-	-	-	-
	2020	1.27*	1.42*	2.77*	5.46*	2.69*	-	-	-
	2050	2.62*	0.07	1.42*	4.11*	4.04*	1.35*	-	-
	2080	5.32*	2.62*	1.27*	1.41*	6.74*	4.04*	2.7*	-

* Significant at 1% probability level through t-Test.

Differences were calculated from the situation listed in the lines minus those listed in the column

Effect on the Internal Environment of Conventional Broiler Housing

The monthly profile of the black-globe humidity index (BGHI) was simulated according to the daily and monthly average air temperature over 30 years of data studied, with the air velocity of 2,0 m/s in the period from 1975 to 2005 (current), and increased in 2°C, 3°C and 5°C for the years of 2020, 2050, 2080 (future projections), respectively, for roofs constructed with ceramic and sandwich tiles, adopting a column height of 3.0 m and roof slope of 25° and 5.7°, respectively (Figures 1 and 2).

Analyzing the BGHI profile, inside of the broiler chicken house equipped with ceramic tiles (Figure 1), for the present and for the future, consequential increases in temperature result in an increasing trend of BGHI. Therefore, the broiler chickens raised in facilities with these characteristics, shall suffer even more with thermal stress in the warmer periods of the year, because the values of BGHI are be found over 75, which is taken as the thermal comfort threshold to broiler chickens (Tinôco, 1988). Considering the monthly average values of BGHI (Figure 1), the current situation shows that thermal comfort conditions covers all months of the year, however, the future projection indicates that in 2020 it should be 2 months of discomfort (Jan and Feb), in 2050 there will be 4 (Jan, Feb, Mar and Dec), and in 2080 there will be 7 (Jan, Feb, Mar, Apr, Oct, Nov and Dec). Situations worst could be happen if they were judged to be the daily high temperature.

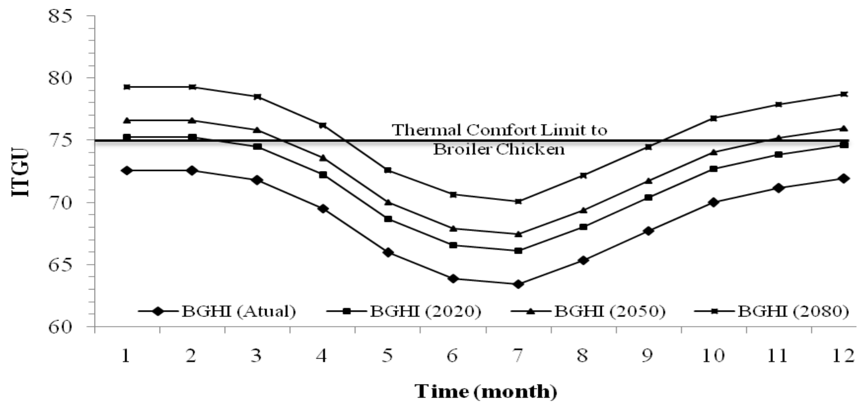

Figure 1. Monthly average black-globe humidity index (BGHI) profiles, calculated from average air temperature and the air velocity of 2.0 m/s in the current period, year 2020, 2050, 2080, for roofs constructed with ceramic tiles, with 3.0 m of column height and 25° of roof sloop.

Similar BGHI profiles were observed for roofs built with sandwich tiles, although the BGHI values were smaller than the ones that were determined for roofs built with ceramic tiles (Figure 2). Based on the monthly average BGHI throughout the year it can be seem that for current situation, 2020 and 2050, the thermal environment inside of the broiler houses can be classified as comfortable. However, in 2080, 6 months (Jan, Feb, Mar, Oct, Nov, and Dec) were classified as uncomfortable for the broiler chickens. Once again, worst prospections can occur during the hottest period of the day is considered.

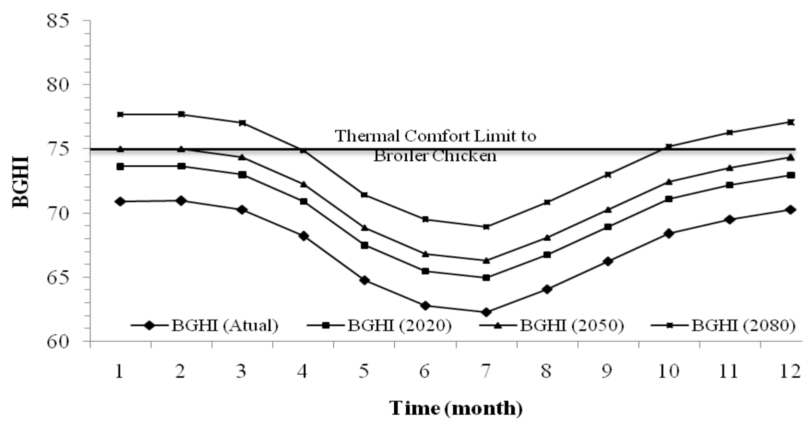

Figure 2. Monthly average black-globe humidity index (BGHI) profiles, calculated from average air temperature and humidity to the air velocity of 2.0 m/s in the current period, year 2020, 2050, 2080, for roofs constructed with sandwich tiles, with 3.0 m of column height and 5.7º of roof slope.

Overall, the simulations shown that the rise in air temperature caused by weather changes can reduce broiler chicken production, once the thermal environment inside of broiler houses will become worse. In addition, the use of tiles with high thermal resistance (e.g. sandwich tiles) can improve the thermal environment, but other improvements should be added, such as, studying new architectural design, use of new materials with higher thermal resistance, use of more effective ventilation and cooling systems, adopt new breeds more tolerant to heat stress, etc.

Conclusions

The increase in air temperature caused by climate change will result in an increase of BGHI inside the broiler chickens houses, negatively affecting its productivity. Moreover, the use of roof materials, with higher thermal resistance will allow the reduction of these effects, although is not be sufficient, which will lead to the study of new technologies in order to provide an environment more suitable for the production of broiler chickens.

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Appendix

T_{bg}	Black-globe temperature, K;
T_{dp}	Dew-point temperature, K.
σ	Stefan-Boltzmann Constant (5,67 x 10^{-8} W m^{-2} K^{-4});
T_i	Temperature of each section around the black-globe, K;
F_i	Form factor of each section around the black-globe;
ν	Air velocity, m/s.