XVII[th] World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

EFFECT OF CONSTRUCTION AND ENVIRONMENTAL FACTORS ON THE PERFORMANCE OF HEATING AND COOLING SYSTEMS FOR POULTRY PRODUCTION

MARIA CLARA DE CARVALHO GUIMARÃES[1], FERNANDO DA COSTA BAÊTA[1], ILDA DE FÁTIMA FERREIRA TINÔCO[1], DÉBORAH CUNHA CASSUCE[1], IRENE MENEGALI[1], JAIRO ALEXANDER OSÓRIO SARAZ[1]

[1] University Federal of Viçosa, Agricultural Engineering Department. Viçosa, Brasil <maria.clara@ufv.br>

CSBE101139 – Presented at Section II: Farm Buildings, Equipment, Structures and Livestock Environment conference

ABSTRACT In agribusiness, the poultry production stood out in recent decades by a trend of technological advances that have transformed the venture into a genuine economic activity. The knowledge of the thermal environment of the facilities allow the evaluation of response to changing weather ahead and offer technical alternatives to ensure adequate performance based on locality. The objective of this study was to evaluate the indoor breeding of broiler chickens under the standpoint of constructive and thermal systems and their correlation. Poultry houses in the city of Videira, Santa Catarina, southern Brazil, during the winter were evaluated. We evaluated the internal heat of the birds, between 07:00 a.m. and 19:00 p.m. and estimated through the psychometrics properties of the air, the internal temperatures of the air associated with a relative humidity of 80% in order to determine how much these temperatures can be reduced by humidifying the environment and subsequently analyzing the relative efficiency of these sheds. In winter conditions, the poultry houses were considered optimal and relative efficiency was isolated based on the low external temperatures. However, the internal thermal conditions were uncomfortable for the birds during the hot days. Moreover, the external temperatures were relatively close to the comfort zone for most of the time. In these times, the systems could be turned off and the curtains opened, providing better thermal conditions and lower power consumption.

Keywords: cooling equipment, building rural, poultry

INTRODUCTION In the Brazilian agribusiness, the production of broilers stood out in recent decades by a trend of increasing technological and ability of coordination between various actors within it. The activity provides the country a prominent position on the world stage. From 2004 became the largest exporter, ahead of the United States and the third largest producer, ahead of the 25 European Union countries (Usda, 2009; Abef, 2009).

In recent decades, the Brazilian poultry industry has undergone major changes. The breakthrough in production occurred in 70 years with the marketing of whole broiler, frozen or chilled. In the 80s, the largest companies have increased production of broiler, to meet a growing demand for this product in the international market and, subsequently, companies, stiving to add value to their products, they began to produce industrial (MATIAS et al., 2003).

In this context, large investments have been made to increase productivity with the welfare of animals, especially in the areas of breeding, nutrition, management and health. However, for the birds can express its full genetic potential, it is also indispensable the development of other areas involved in production, such as the environment: aseptic and thermally adapted to the needs of animals.

When planning a facility to promote their thermal conditioning desirable, it is necessary to know the characteristics of the natural environment that compose the local weather and compare them with the conditions of physiological comfort of the birds for which the installation is projected through systematization of this information. Comparing the two situations, deduce the means to obtain them and elaborate technically and constructive solutions. For the reason shown, it is important to describe yours construction and operational aspects, allowing drawing a comparative analysis to identify systems that can show better results.

The objective of this research was conduct an architectural and environmental inventory of facilities used in the poultry industry in broilers in southern Brazil, through the analysis, description and evaluation of buildings and thermal characteristics of these installations.

METHODS AND MATERIALS Data were collected in an experiment conducted on property commercial poultry in the city of Videira, Santa Catarina, southern Brazil, located at latitude 27°00'S and longitude 51º09'O, at an altitude of 750 m. The climate, according to the classification of Köppen, is Cfb (temperate, humid mesothermal and mild summer) with average temperatures between 11 and 20°C and relative humidity averages between 75 and 87%. The experimental phase was conducted in winter conditions, with broiler Cobb, created in density of 20 birds/m², and comprised from 15 to 32 days of life of birds. To measure the temperature and relative humidity in the indoor environment were used dataloggers HOBO® brand, with a resolution of 0.1°C for temperature and humidity for 1%, and accuracy of ± 0.5°C and ± 1% respectively installed inside each house at the level of birds, 0.25 m above the bed.

To characterize the architectural of the facilities sought to address the constructive aspects in each production unit through information contained in the diaries of their research and photographic analysis. The building typology were characterized according to the orientation and dimensions of sheds, height of ceiling height, type of closure, presence of liners under coverage, types of tiles, eaves, slope, presence of sprinkler on the roof beyond the types of materials used in the structure. The thermal artificial systems were characterized according to the type of ventilation, type of cooling evaporative, adopted management, survey of maintenance, cleaning and scaling these systems through information in the respective published works and diaries research. The calculation was made according to the management usually adopted by companies.

Was studied, using graphs of continuous surface, the behavior of temperature and relative humidity at the level of birds depending on time of day, between 07:00 a.m. and 19:00 p.m., understanding the range of incidence of solar radiation, corresponding to the critical period of heat stress within of the building. In these graphs were plotted plans for maximum value of relative humidity at 80% maximum value considered permissible and which represents the potential reduction of temperatures air by evaporative cooling (BAIÃO, 1995; BAÊTA & SOUZA, 1997; MOURA, 2001; TINÔCO, 2001) in order to compare the behavior with the ideal of domestic comfort required by birds (Freeman, 1965; Avila, 2004; FURLAN, 2006) and that considered as efficiency maximum operation of evaporative cooling SILVA, 2002). Similarly, we generated graphs of traces curves for better visualization of the values of relative humidity air.

From the evaluation of internal thermal behavior were estimated by psychometrics properties of air through interactive process, the internal temperatures of the air for hours the entire production cycle according to the average atmospheric pressure place if the relative humidity was high at 80% per evaporative process, maximum efficiency of each system, in other words, these temperatures were associated with a relative humidity of 80% with to determine how these temperatures can shorten with humidifying the environment.

According to the new hourly values of temperature, it was estimate the number of hours of thermal comfort in terms of increased efficiency of evaporative cooling systems inside the poultry house, thus allowing the evaluation of systems as the temperature variations of the facilities studied combining the architectural features, and propose alternative solutions and techniques that can lead to an adequate thermal performance to the location where he is inserted.

To evaluate the poultry house was considered the relation between external temperature and internal temperature, called relative efficiency of the poultry house. In winter conditions, to temperatures below 18ºC, the lower the value found, the more efficient the shed to preserve the heat internally.

RESULTS AND DISCUSSION

Architectural evaluation The Table 1 shows the architectural of the study, in simplified form.

Table 1.Architectural characteristics of the facilities with negative pressure in winter conditions and aluminum roof

Constructive characteristics	
Orientation	east-west
Dimensions (width x length)	12,00 x 100,00 m
Area	1200,00 m²
Height	2,80 m
Muret side	0,30 m
Curtains	Polietileno
Lateral closing	Wire screen (mesh 2.5 cm)
Closing front side	Wood
Lining	There is no presence is liners
Coverage	Aluminum
Eaves	0,50 m
Inclination	30%
Structure	Metal structure on the roof supported by concrete pillars
Remarks	Materials curtains and cover are in good repair

We evaluated two poultry houses similar (Figure 1), the same productive core, positioned side by side.

Figure 1. Outside view of the poultry house in Videira, Santa Catarina, Brazil

The structure of the roof was metal, supported on concrete columns, there was no presence of lining (Figure 2) and tiling of aluminum had no paint.

Figure 2. Inside view of the poultry house in Videira, Santa Catarina, Brazil

The poultry houses evaluated tended to meet the recommendations regarding the natural thermal environment according to the suggested in the literature, except the lack of lining, still exhibits, architectural characteristics with what is proclaimed in this region of Brazil.

Evaluation of thermal conditioning artificial systems The Table 2 presents the characteristics of systems of thermal artificial of the poultry house in the study, in simplified form.

Table 2. Characteristics of the thermal artificial with negative pressure conditions of the poultry house in winter and aluminum covering

Ventilation systems	
Type	Exaustor – com 6 pás em chapa galvanizada
Numbers	7
Localization	Face west
Vazão	560 m³/min
Cooling Systems	
Type	Nebulização
Localization	Linhas transversais abaixo da cobertura

The poultry house were equipped with ventilation by negative pressure in tunnel mode, composed of seven hoods located in side west, with air inlet at the opposite end.

Additionally, inside of the poultry house was fogging system, distributed in transverse lines with respect to length. The drive took place in accordance with the internal temperature of poultry house and bird age, and occurred in stages in working groups.

According to preliminary calculations, the number of exhaust is lower than recommended, because considering the air velocity of 2.5 m / s and the dimensions of the shed, an air volume equal to 5040.0 m^3 of the shed must be removed per minute. Thus, for range 560 m^3/min, it would take about 9 units. The shed in the study had 7 exhaust.

Evaluation of environmental thermal conditions of the systems of thermal artificial
The evaluation of the thermal environment inside the poultry house, used the hourly data of temperature and relative humidity of indoor air, the level of birds, from 07:00 to 19:00 from 15 to 32 days of life for birds, for 2 sheds evaluated.

The behavior of relative humidity from inside the POULTRY HOUSE 1 depending on the temperature and time of day, is represented in the form of solid surface and the curves plotted in Figure 3.

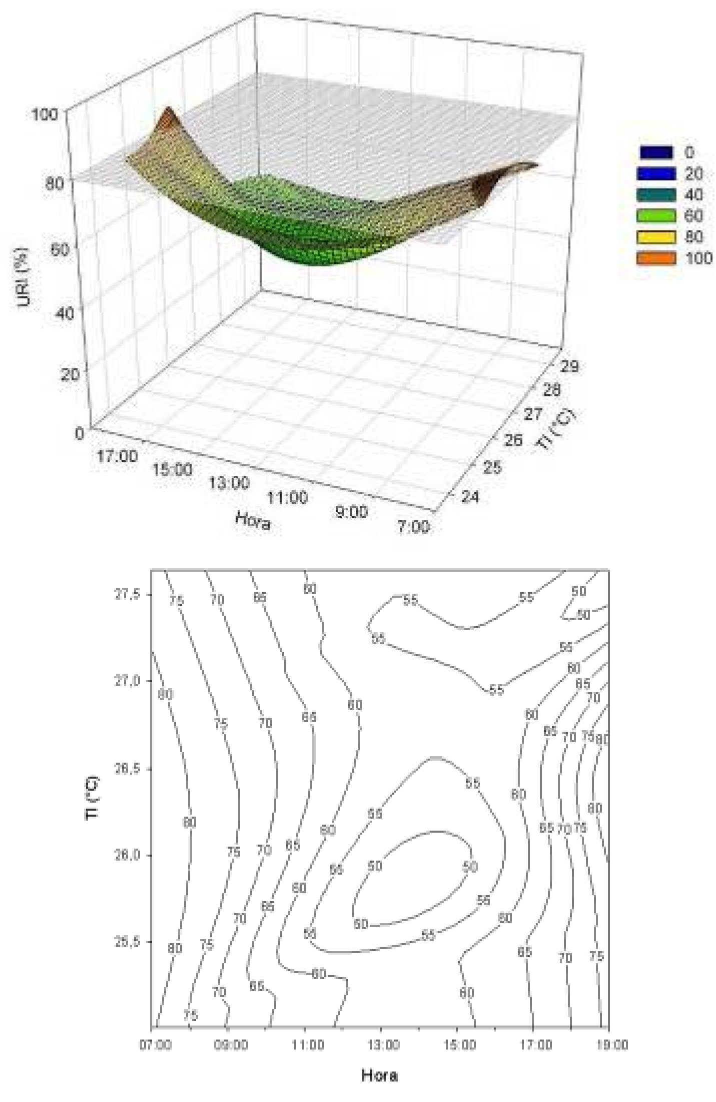

Figure 3. Behavior of relative humidity in the indoor environment, from 15 to 32 days of age for birds, depending on air temperature and time of day, to a storage area with negative pressure system in winter conditions and aluminum roof: POULTRY HOUSE 1 (Videira - Santa Catarina, Brazil)

According to Figure 3, one can observe that the internal relative humidity was at about 85% of the time below 80%, between 50 and 75%. Moisture levels above 80% were observed only for internal temperatures between 25 and 29°C, between 07:00 a.m. and 08:00 a. m. and after 6:00 p.m. for an average temperature of 26°C. In general, if there was a system of evaporative cooling, this would present the possibility of potential, proportional to the difference in humidity between the current value and 80%.

Whereas the evaporative cooling system could improve efficiency, was estimated by the psychrometric properties of air, the hourly internal temperatures of the air associated with the relative humidity of 80%, in order to determine how these temperatures could be reduced by humidifying the environment for POULTRY HOUSE 1, as shown in Figure 4. For the discussion sequence was represented in this figure the temperature range between 18 and 24ºC, considered the thermal comfort for birds as well as the line is at a temperature of 29°C, suggesting a tolerance.

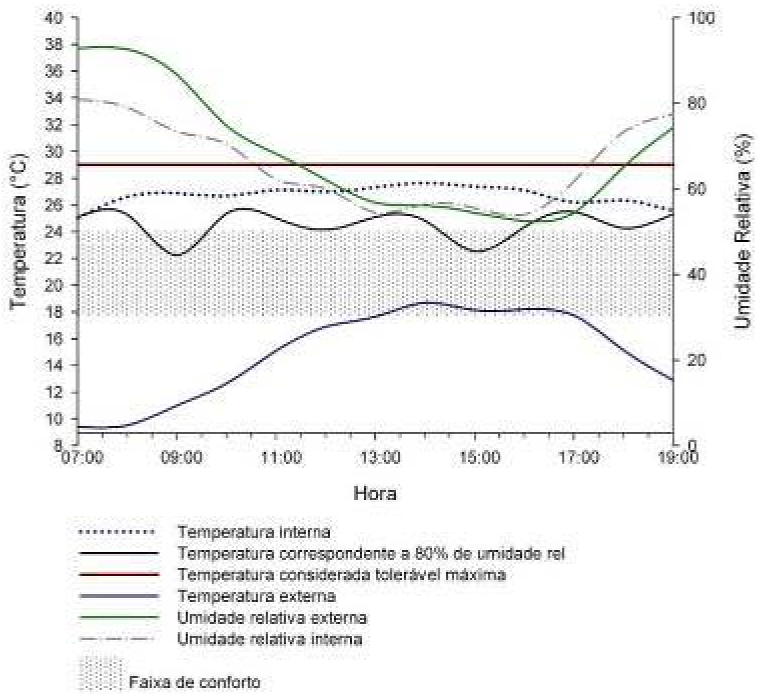

Figure 4. Mean values of internal and external temperature, temperature corrected to 80% internal relative humidity, from 15 to 32 days of life for birds, depending on time of day, and represent the range of temperature comfort and temperature tolerance: POULTRY HOUSE 1 (Videira - Santa Catarina, Brazil)

According to Figure 4, the internal temperatures were above the range of thermal comfort throughout the day, ranging between 25 and 27°C, while all the time, was below the maximum temperature considered tolerable for birds.

You can check in the previous figure that during the hottest hours of the day, between 1 p.m. and 5 p.m., the temperatures outside reached 18°C with relative humidities near 57%, and the internal temperature reached about 27°C with humidity near 55%. It was also observed in this figure that even improving the efficiency of evaporative cooling, the temperature of the air would change relatively little, being between 22 and 25°C, but would be closer to the place of comfort of the birds.

It is noteworthy that the average temperatures outside, between 11:00 a.m. and 6:00 p.m., were near the lower limit of the comfort range for birds. During this time, the thermal condition could be turned off and the curtains open, providing ample ventilation, with consequent improvement of thermal environment for birds and reduced power consumption.

Due to the low external temperatures between 07:00 a.m. and 11:00 a.m., one can infer that the material closing the poultry house, especially the curtains and cover, with minor adjustments could provide better thermal comfort for birds.

The behavior of relative humidity from inside the POULTRY HOUSE 2 as a function of temperature is shown in Figure 5.

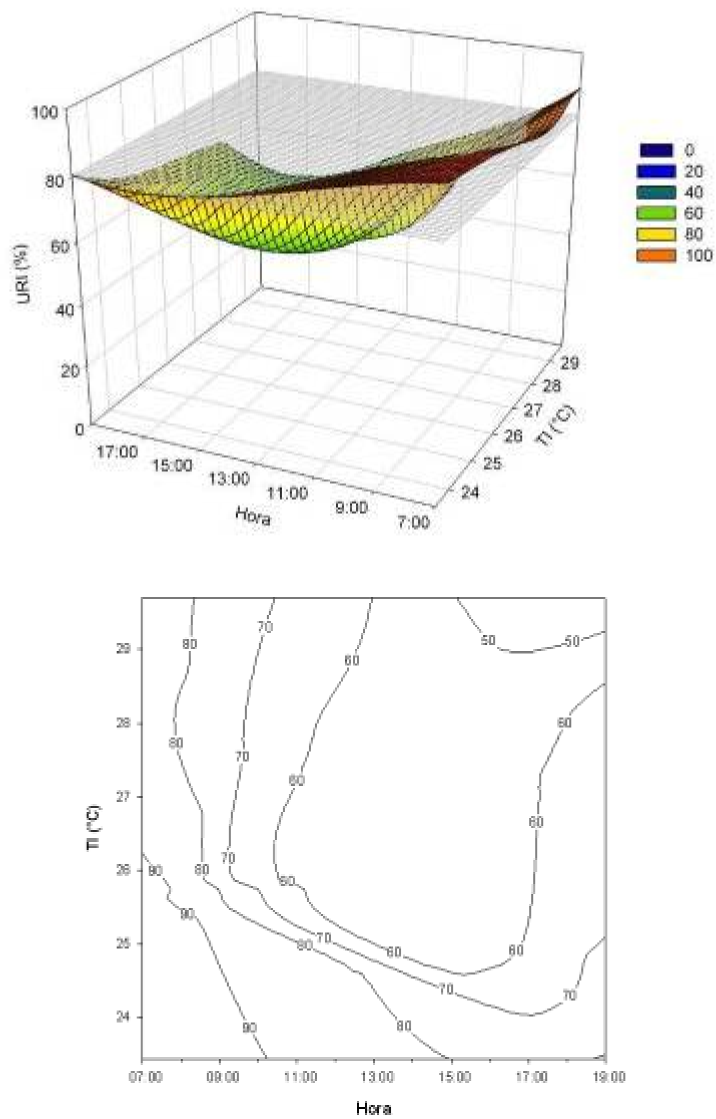

Figura 5. Behavior of relative humidity in the indoor environment, from 15 to 32 days of life for birds, depending on air temperature and time of day, to a storage area with negative pressure system in winter conditions and aluminum tiles:

POULTRY HOUSE 2 (Videira - Santa Catarina, Brazil)

According to Figure 5, one can observe that the internal relative humidity was at about 69% of the time below 80%, between 50 and 70%. Moisture levels above 80% were observed for internal temperatures between 23 and 30 ° C, between 07:00 a.m. and 3:00 p.m. In general, if there was a system of evaporative cooling, this would present the possibility of potential, proportional to the difference in humidity between the current value and 80%.

Whereas the evaporative cooling system could improve efficiency, was estimated by the psychrometric properties of air, the hourly internal temperatures of the air associated with the relative humidity of 80%, in order to determine how these temperatures could be reduced by humidifying the environment for POULTRY HOUSE 2, as shown in Figure 6.

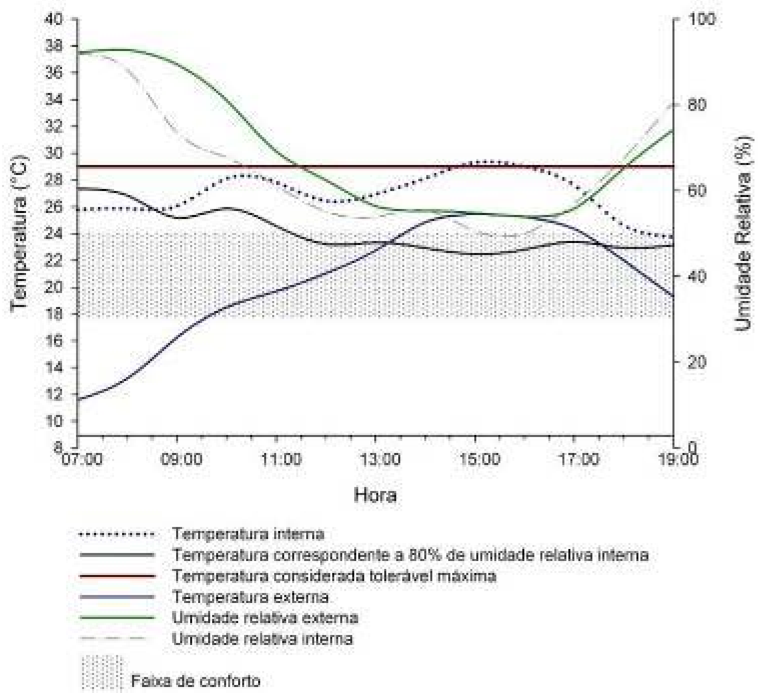

Figure 6. Mean values of internal and external temperature, temperature corrected to 80% internal relative humidity, from 15 to 32 days of life for birds, depending on time of day, and represent the range of temperature comfort and temperature tolerance: POULTRY HOUSE 2 (Videira - Santa Catarina)

According to Figure 6, the internal temperatures were above the range of thermal comfort throughout the day, ranging between 24 and 29°C, and in 15% of the time, was above the maximum temperature considered tolerable for birds. And also that from 09:30 a.m. to 07:00 p.m. the external temperatures were between 18 and 26°C with relative humidity reaching 57%. It is also observed in this figure that by improving the efficiency of evaporative cooling, especially during the hottest hours of the day, the temperature inside the air would change significantly, remaining within the zone of comfort of the birds.

Note that the values of observed temperatures outside the thermal condition could be turned off and the curtains open in much of the time, providing ample ventilation, with consequent improvement of thermal environment for birds and reduced power consumption. The evaporative cooling system could bring benefits only between 01:00 a.m. and 05:00 p.m.

Due to the low external temperatures between 07:00 a.m. and 09:00 a.m., one can infer that the material closing the barn, especially the curtains and cover, with minor adjustments could provide better thermal comfort for birds.

To evaluate the thermal behavior of the barn was considered the relationship between external temperature and internal temperature, which will be called relative efficiency. This parameter, in winter conditions, to temperatures outside below 18°C, the lower the score, the greater the efficiency of the poultry house to alleviate the external temperature in relation to temperature.

The Figure 7 represents the relative efficiency of the POULTRY HOUSES 1 and 2. During the period, the average temperature outside was 15 º C.

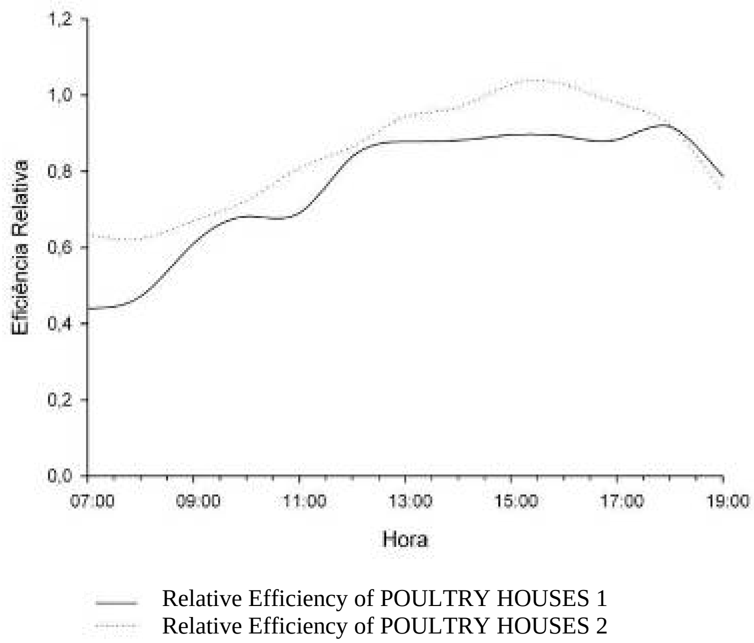

Figure 7. Relative Efficiency: POULTRY HOUSES 1 and 2 (Videira - Santa Catarina, Brazil)

According to Figure 7, the relative efficiency of POULTRY HOUSES 1 during the cooler hours of the day, between 07:00 and 10:00, with average value of 0.39 and POULTRY HOUSE 2 average value of 0.54. Throughout time, the relative efficiency was less than 0.80. The smaller these values better able to isolate the shed in the low outside temperatures, implying that the shed had an estimated relative efficiency of the optimal period.

The behavior of the sheds was efficient in isolating good on the low outside temperatures in the cooler hours of the day. However, the environmental thermal conditions presented themselves uncomfortable internal heat to the birds. The evaporative cooling system, in theory, could reduce the internal temperatures considerably at times of peak solar radiation.

It is noteworthy that the temperatures outside were relatively close to the comfort range for birds in much of the time. In this interval the evaporative cooling system could be shut down and the curtains open, providing ample ventilation, with consequent improvement of thermal environment for birds and reduced power consumption.

CONCLUSION The poultry houses evaluated tended to meet the thermal, natural as suggested in the literature, with further architectural features with what is advocated in the region, sheds negative pressure systems associated with evaporative cooling (misting and evaporative plates) with tiles galvanized steel. The number of hoods has been below expectations and internal temperatures were above the comfort range for birds, and in some periods, above the maximum allowable temperature, and improving the system of evaporative cooling could contribute greatly to the reduction of internal temperature to the levels of comfort range. The warehouses had considered optimal relative efficiency in isolating the low outside temperatures in the cooler hours of the day. However, the environmental thermal conditions presented themselves uncomfortable internal heat for birds in the warm period and the system of evaporative cooling, in theory, could reduce the internal temperatures considerably. As the temperatures outside were relatively close to the comfort range for birds in much of the time in this interval, the evaporative cooling system could be shut down and the curtains open, providing ample ventilation, thus improving the environmental thermal conditions for birds and reduction in power consumption.

Acknowledgements. Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq, for the consent of scholarship.

REFERENCES

ABEF – Associação Brasileira dos Produtores e Exportadores de Frango. Relatório anual 2008/2009. Available at: http://www.abef.com.br/portal/_clientes/abef/cat/Abef%0RA_4021.pdf. Accessed: 02 august 2009.

Baião, N. C. 1995. Efeitos da alta densidade populacional sobre o ambiente das instalações avícolas. Simpósio internacional sobre ambiência e instalações na avicultura industrial 67:75. (Abstr.)

Baêta, F.C., Souza, C. F. 1997. Ambiência em edificações rurais – conforto animal. 246 p. Editora UFV, Viçosa, BRA.

Matias, A. B.; Meirelles, J. L. F.; Caldeira, L. C. Estratégia, investimento e competitividade da indústria avícola brasileira. Available at: www.ead.fea.usp.br/semead/6semead/PNEE/019PNEE%20-%20Estrat%E9gia%20Investimento%20e%20Competitividade.doc. Accessed: 22 august 2007.

Moura, D. J. de M. p. 75-148. *In* SILVA, I. J. O. da (eds.). Ambiência da produção de aves de corte. FUNEP, Piracicaba, São Paulo, BRA.

Silva, C. E. 2002. Comparação de painéis evaporativos de argila expandida e celulose para sistemas de resfriamento adiabático do ar em galpões avícolas com pressão negativa em modo túnel. MS Thesis. Viçosa, MG: Federal University of Viçosa, Agricultural Engineering Department

Tinôco, I.F.F. 2001. p. 1-74. *In* SILVA, I. J. O. da (eds.). Ambiência da produção de aves de corte. 2001. FUNEP, Piracicaba, São Paulo, BRA.

USDA – United States Department of Agriculture. Livestock and poultry: world markets and trade. Available at: http://www.fas.usda.gov/dlp/circular/2009/livestock_poultry_04-2009.pdf. Accessed: 22 de agosto de 2009.