RESEARCH ARTICLE OPEN ACCESS

Laboratory Proposal for Studies on Poultry Environment

Schiassi, L.[1]; Yanagi Junior, T.[1]; Abreu, L.H.P.[2]; Reis, G.M.[3]; Damasceno, F.A.[1]; Silva, G.C.A.[2]; Campos, A.T.[1]
[2] Agricultural Engineering, MS in Agricultural Engineering, Universidade Federal de Lavras – MG
[1] Agricultural Engineer, PhD Professor, Department of Engineering, UFLA/ Lavras – MG
[3] Undergraduate in Computer Science, Department of Computer Science, UFLA/ Lavras – MG

Abstract
The goal of the present work was the instrumentation and validation of a laboratory equipped with a control system for air temperature (t_{air}), relative air humidity (RH) and air velocity (V) to study the environment for small animals. An experimental was equipped with two air conditioners to manage basic t_{air} and RH in order to work. Four wind tunnels, with partial recirculation of air were installed in the room. Each tunnel features two electric heaters and two humidifiers divided into two operation stages. The air velocity is manually controlled by potentiometers connected to exhaust fans. A system to acquire data and control climatic variables was installed in the laboratory and it consisted of a datalogger, a multiplexer channel, a relay controller , t_{air} and RH sensors, sensors for measuring water temperature and digital helix anemometer to measure air velocity. The results showed that the system presented deviations of ± 0.19 °C, ± 0.75% and ± 0.05 m s^{-1} for t_{air}, RH and V, respectively, when comparing the values measured inside the tunnels to those previously established (setpoints).
Key words: controlled environment, instrumentation, climatic chamber

I. INTRODUCTION

To maximize productivity, it is imperative to combine a high genetic potential of the breed to a diet with adequate nutritional level in an aseptic environment, adjusted to the needs of the animals. Thus, the environment plays a fundamental role in modern animal production, since it aims at achieving high productivity in relatively small spaces and time. The quantification of the animal responses to biophysical factors is an important factor in researches aimed at increasing animal welfare and production efficiency.

In this context, the use of climatic chambers presents the advantage of allowing control over environmental factors for the development of experiments with animals. Researches on control of the environment for animals employing these systems have been performed by several researchers.

Oliveira Neto et al. (2007) determined methionine + cystine requirements for broilers from 22 to 42 days old, kept in thermo-neutrality zone. Oba et al. (2007) evaluated the composition and quality of breast meat from broilers fed diets supplemented with chromium complexed to yeast, raised under different temperature conditions.

Oliveira et al. (2010) studied the effects of reduced levels of crude protein in the diet over performance and yield of cuts in growing male broiler kept under heat stress. Silva et al. (2009) evaluated the performance of broilers at 21 days of age reared under different temperatures and receiving, in the pre-initial stage, diet with or without yeast extract and / or prebiotics.

Siqueira et al. (2007) studied the effects of dietary lysine levels in the diet and the environment temperature over performance and carcass characteristics of broilers from 22 to 42 days old. Ferreira et al. (2009) evaluated the effects of heat stress on cattle. Kiefer et al. (2009) evaluated the behavior, physiological responses and performance of growing swine subjected to different temperatures.

Maia et al. (2009) studied the effects of temperature and air movement over thermal insulation of sheep fleece. Silva et al. (2011) evaluated the duration of ractopamine supplementation in the diet of finishing gilts kept under high temperature. Pereira et al. (2007) studied the effects of air temperature, strain and time of the day on behavior of broiler breeders.

Pereira et al. (2008) estimated the welfare of broiler breeders as a function of frequency and duration of behaviors expressed by the birds. Sanches et al. (2010) evaluated the performance and quantitative characteristics of barrows carcass kept under comfortable thermal environment and fed diets containing different levels of ractopamine.

Moreover, the determination of the variables air temperature (t_{air}), relative air humidity (RH), air velocity (V) and black globe temperature (t_{bg}), besides allowing to determine a profile of the environmental conditions, it allows the calculation of thermal comfort indices which are used to qualify and quantify animal discomfort, which in turn is related to the physiological responses and productive performance of animals, and it is an evaluation method that is indirect and practical (Damasceno et al., 2010).

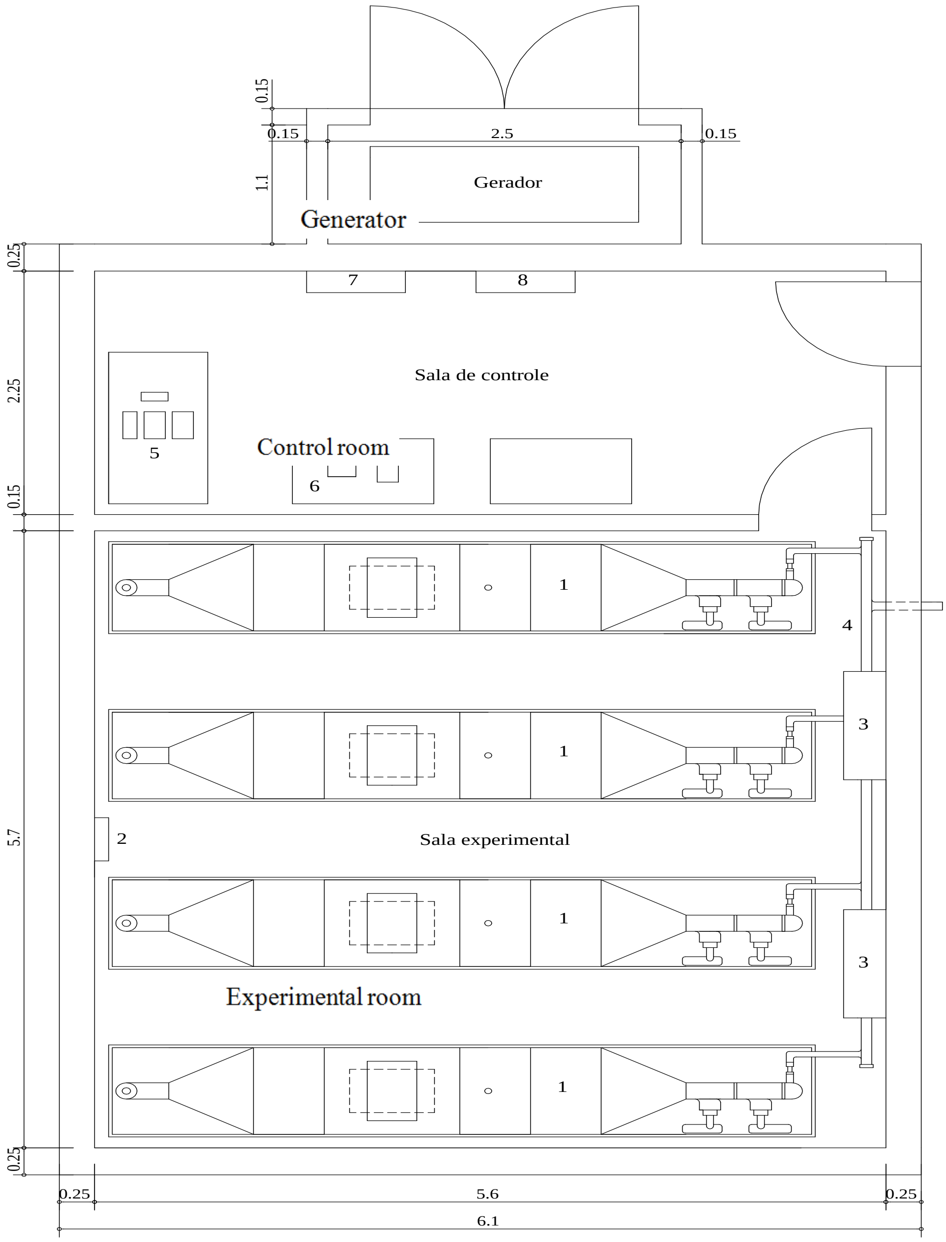
Thus, the present work aimed at the instrumentation and validation of a laboratory equipped with control system for t_{air}, RH and V in the wind tunnels to study environment for small animals.

II. MATERIAL AND METHODS

With the goal of studies on physiological and behavioral responses of small animals (broilers, hens, swine, quail, etc..), a laboratory consisting of four wind tunnels with partial recirculation of air and automatic temperature and relative air humidity control and manual control of velocity was built and instrumented.

Physical structure and wind tunnels

An experimental room, measuring 5.6 x 5.7 m with a 3.0 m high ceiling, was equipped with two 18,000 BTUs air conditioning systems to manage basic t_{air} values to maintain the desired environment within the experimental room (Figure 1).



1. Wind tunnels
2. Contactors
3. Air conditioners
4. Ducts to exhaust the air
5. Acquisition, storage and control modules
6. Computer for programming
7. System's electrical circuit panel
8. Generator control panel

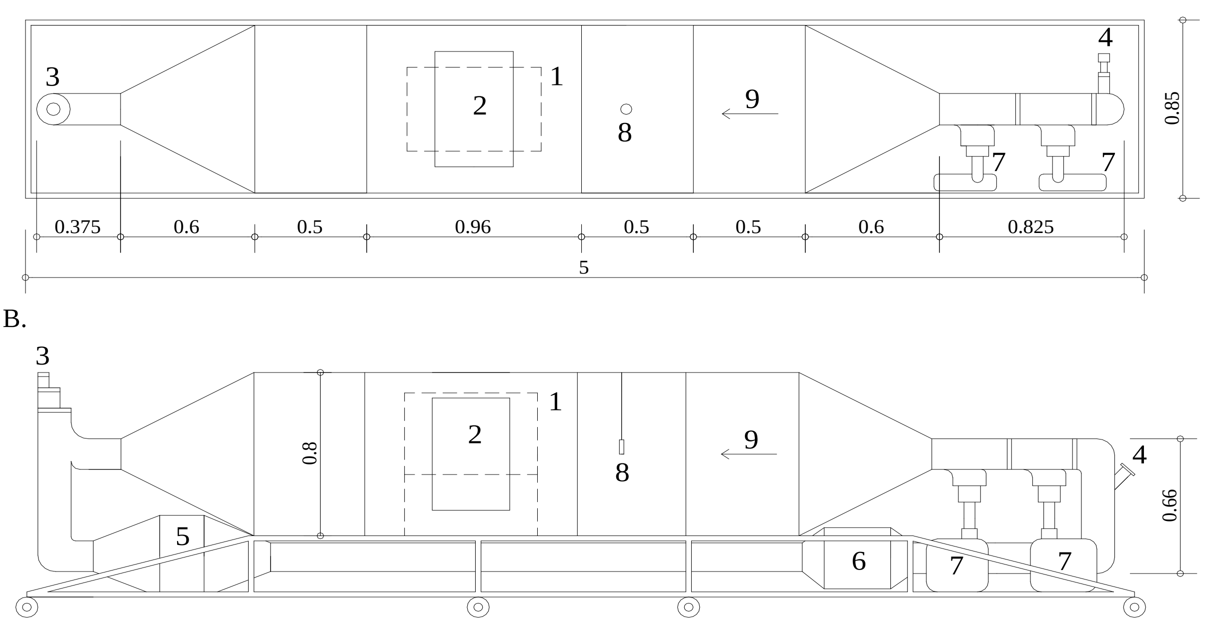
Figure 1. Illustrative scheme of the wind tunnels installed inside a room equipped with system cooling

Inside the room four wind tunnels (0.8 x 5.0 m) were installed in order to obtain different thermal conditions to which small animals may be subjected. The tunnels made of steel boards and PVC tubes have partial recirculation of air (Figure 2).

Each tunnel features two 600 W electric heaters and two humidifiers with average mist capacity of 300 mL.h^{-1}, divided into two operation stages. Each heating stage can be expanded up to 1800 W. The first stage allows the t_{air} and RH inside each tunnel to reach a minimum reference value and the second stage is used to make a more accurate control of these variables.

The air velocity is manually controlled through potentiometers connected to 0.40 m wide exhaust fans and maximum flow of 4200 m^3 h^{-1}. The area allocated for the animal is covered with highly transparent plastic film to allow the capture of digital and thermo-graphic images, and features a cage with an area equal to 0.24 m^2 (0.60 x 0.40 m) and 0.40 m high, fenced with wire mesh to lodge the animals.

A.



1. Cage for the animals
2. Windows with plastic film
3. Air entrance
4. Air exit
5. Fans
6. Heaters
7. Nebulizers
8. Sensors
9. Air flow direction

Figure 2. Top (a) and lateral (b) views of the wind tunnel

Measurement, instrumentation and control

A system for acquisition and control of climatic variables was installed in the laboratory, comprising a datalogger (CR1000, Campbell Scientific), a multiplexer channels (AM16/32B, Campbell Scientific), a relays driver (SDM-CD16AC, Campbell Scientific), t_{air} and RH sensors (HMP45C, Vaisala), sensors for measuring the water temperature (108 Vaisala), T-type thermocouple to measure the air temperature inside (T_{room}) and ouside (t_{ext}) the experimental room, and the black globe temperature was measured through a T-type thermocouple installed in black globes.

The electrical heaters and humidifier were connected to the datalogger CR1000 through 16 channels from the relays driver (model SDM-CD16AC 16 channel, AC/DC controller, Campbell Scientific) connected to 16 electromagnetic relays (Figure 3).

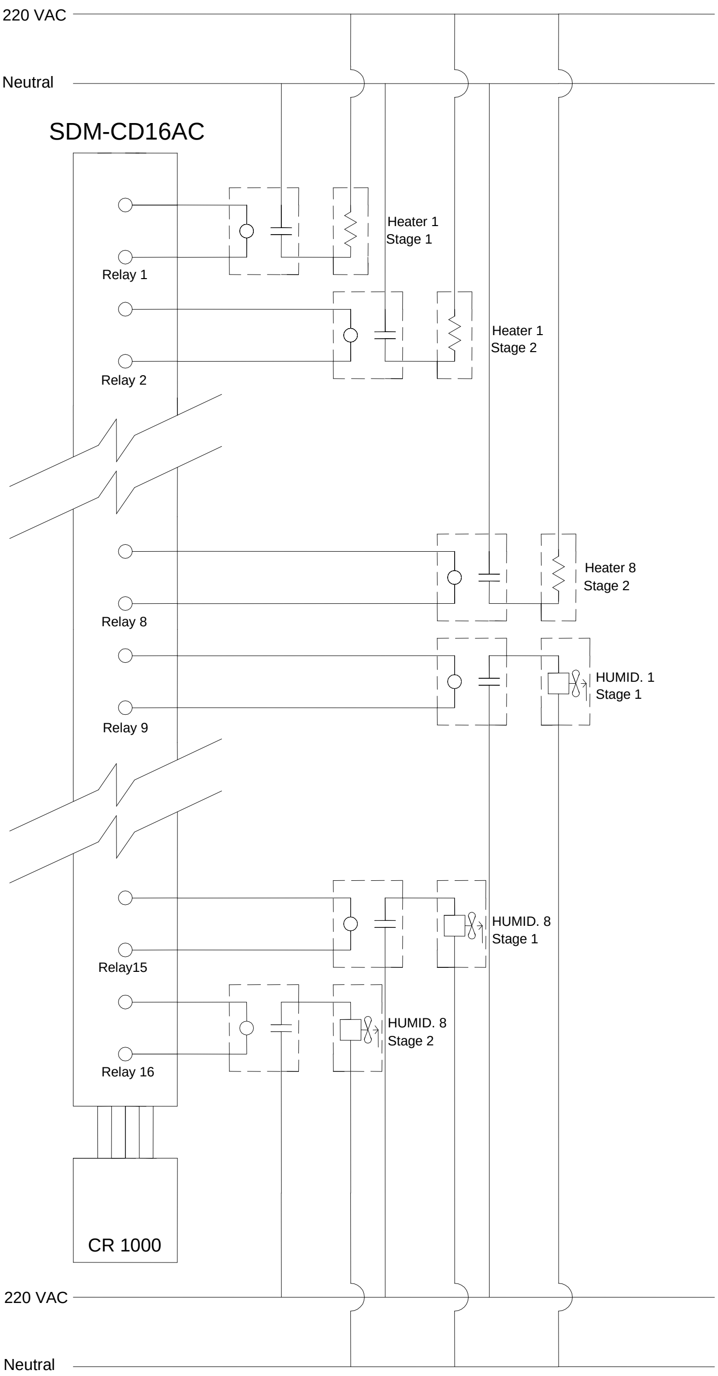


Figure 3. Simplified scheme representing the electric circuit for t_{air} and RH control inside the wind tunnels

The control scheme for t_{air} and RH through two operation stages followed the methodology adopted by Yanagi Junior et al. (2002), shown in Figure 4. The first stage is activated when the t_{air} reaches a value below t_{air} - Δt_{air1}, as Δt_{air1} represents a reliable value for the first stage in relation to the desired temperature, and is disabled when t_{air} reaches a value above $t_{air} + \Delta t_{air1}$. The second stage is activated when the t_{air} is under the desired value and is disabled when the t_{air} surpasses that same value.

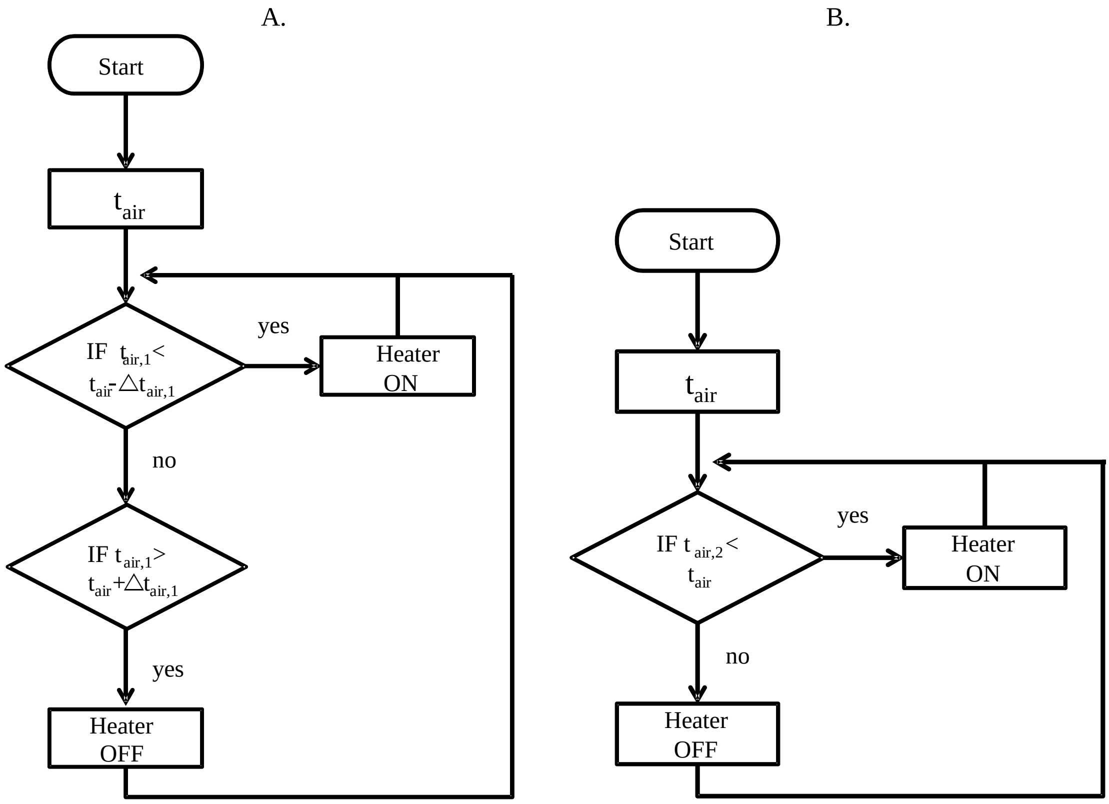


Figure 4. Flowchart illustrating the logic of t_{air} control for the stages 1 (a) and 2 (b). The same logic is applied to RH control

The velocity values for the air inside the wind tunnel were measured through a digital anemometer. Thus, the values for air velocity was obtained in 15 points distributed over an imaginary net located in the transversal section of the cage and moved 0.15 m in the longitudinal direction (Figure 5). Three replicates were performed for each point, totaling 45 data points for each wind tunnel.

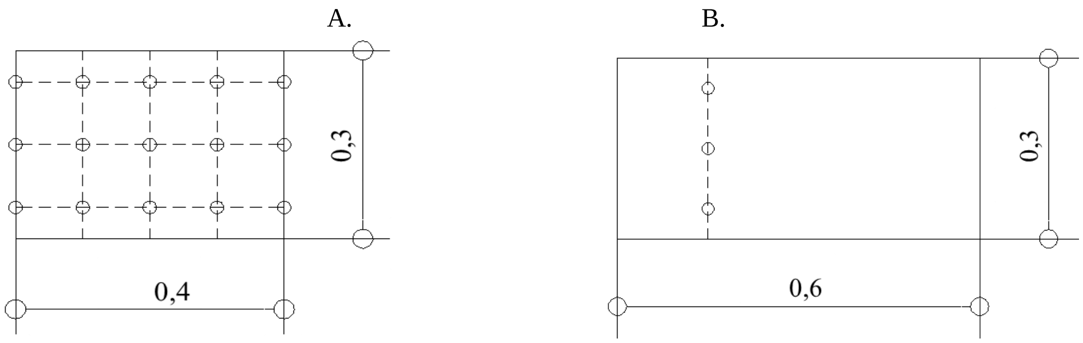


Figure 5. Representation of the measurement points for air velocity in the traversal (a) and longitudinal (b) sessions of the cage

A system with four digital cameras (TRENDnet, model TV-IP422W) equipped with wireless communication was installed in order to monitor animal behavior for later analysis, and surface temperature of the animals was monitored through an infrared camera (Fluke, model TI55FT20/54/7.5).

The values of t_{air}, RH, T_{room} and t_{ext} for each set point (previously established value of air temperature) were measured and recorded at intervals of 10 seconds for a period of approximately eight hours, totaling 2880 logs, without the presence of animals within the wind tunnels.

III. RESULTS AND DISCUSSION

In order to calibrate the system, the capacity of each tunnel to maintain a desired t_{air} and RH (set point) was evaluated. Therefore, four t_{air} were tested (24, 27, 30 and 33 ° C) for an RH at 60 %. It was found that for the desired temperatures of 24 and 27 °C it was necessary to use only the first heating stage, while for temperatures of 30 to 33 °C the two stages were used. The nebulizers always operated in two stages, regardless of the temperature. The results obtained from the calibration are listed in Table 1 and the boxplots temperatures of 24, 27, 30 and 33 ^{o}C, and a relative humidity of 60% are shown in Figure 6.

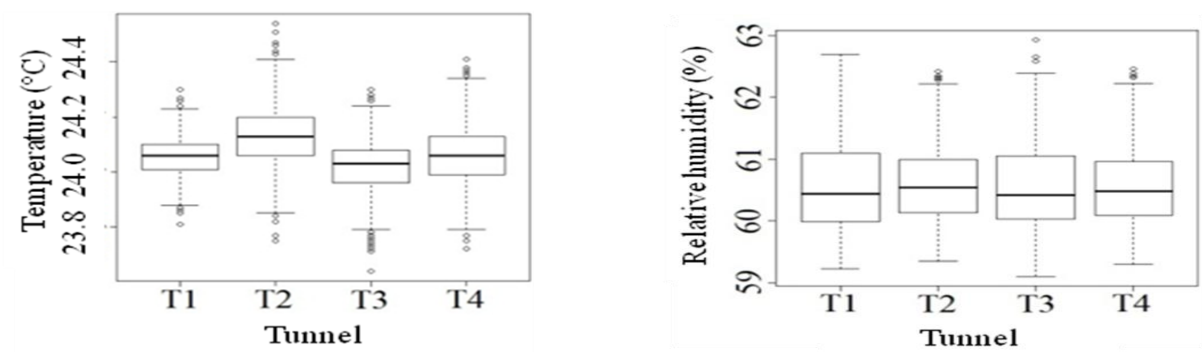
In researches conducted by Silva et al. (2011), Oliveira et al. (2010), Sanches et al. (2010) and Oliveira Neto et al. (2007) , within the chambers, deviations of 1.30 °C, 0.60 °C, 2.90 °C and 0.50 °C were observed, respectively for t_{air} and 6.8, 3.2, 7.3 and 3.1%, respectively, RH, while in the present study, the maximum deviations were 0.19 and 0.75% for t_{air} and RH, respectively, indicating a better ability to control the environment. This ability to maintain the set point is due mainly to the partial recirculation of air in the wind tunnels as well as the inherent characteristics of the system and the handling.

Table 1. Environmental conditions observed in the wind tunnels during the calibration period

Tunnel	Temperature (°C)					Relative humidity (%)				
	set	average ± sd	med	min	max	set	average ± sd	med	min	max
1	33	32.9 ± 0.2	32.9	32.5	33.5	60	60.1 ± 0.7	60.1	57.1	62.3
	30	30.0 ± 0.2	30.0	29.6	30.4	60	60.1 ± 0.7	60.1	58.3	62.8
	27	27.0 ± 0.1	27.0	26.7	27.2	60	60.4 ± 0.6	60.4	59.0	63.3
	24	24.1 ± 0.1	24.1	23.8	24.3	60	60.6 ± 0.7	60.4	59.2	62.7
2	33	33.0 ± 0.2	33.0	32.6	33.5	60	60.2 ± 0.5	60.2	58.3	62.2
	30	30.1 ± 0.2	30.1	29.6	30.6	60	60.3 ± 0.5	60.3	59.0	62.9
	27	27.0 ± 0.1	27.0	26.7	27.4	60	60.5 ± 0.6	60.4	59.2	62.1
	24	24.1 ± 0.1	24.1	23.8	24.5	60	60.6 ± 0.6	60.5	59.4	62.4
3	33	32.9 ± 0.2	32.9	32.4	33.5	60	60.1 ± 0.6	60.1	58.6	62.2
	30	30.0 ± 0.2	29.9	29.4	30.4	60	60.1 ± 0.7	60.1	58.4	62.8
	27	26.9 ± 0.1	26.9	26.6	27.2	60	60.4 ± 0.6	60.3	59.0	62.5
	24	24.0 ± 0.1	24.0	23.6	24.3	60	60.5 ± 0.7	60.4	59.1	62.9
4	33	32.9 ± 0.2	32.9	32.5	33.4	60	60.1 ± 0.6	60.1	58.0	62.6
	30	29.9 ± 0.2	29.9	29.5	30.4	60	60.1 ± 0.8	60.0	58.0	62.8
	27	26.9 ± 0.1	26.9	26.4	27.2	60	60.3 ± 0.6	60.3	58.7	62.9
	24	24.1 ± 0.1	24.1	23.7	24.4	60	60.6 ± 0.6	60.5	59.3	62.5

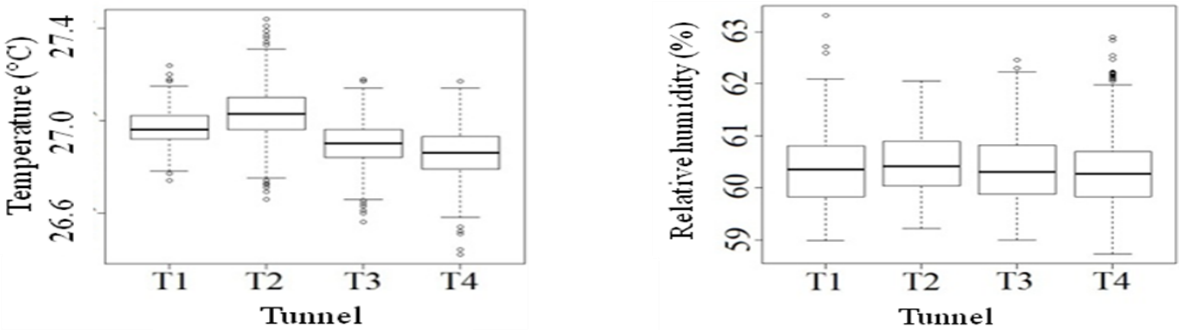
sd: standard deviation; med: medium; min: minimum; max: maximum

A.



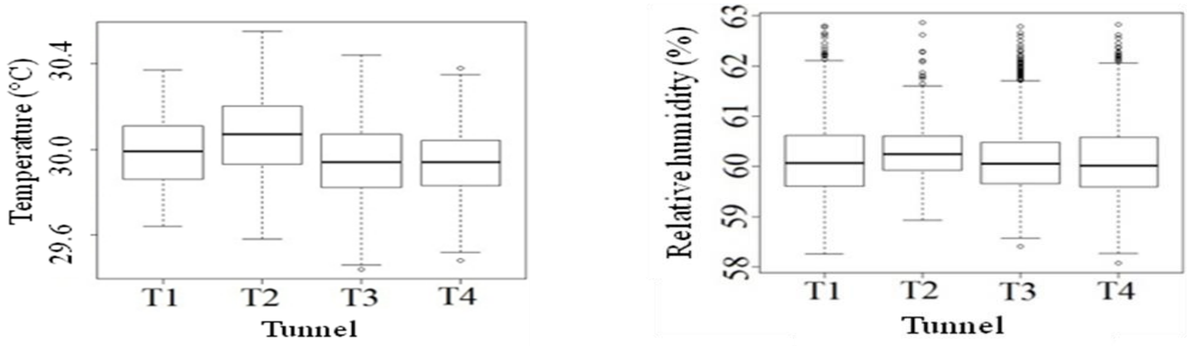
Set point at 24^{o}C Set point at 60%

B.



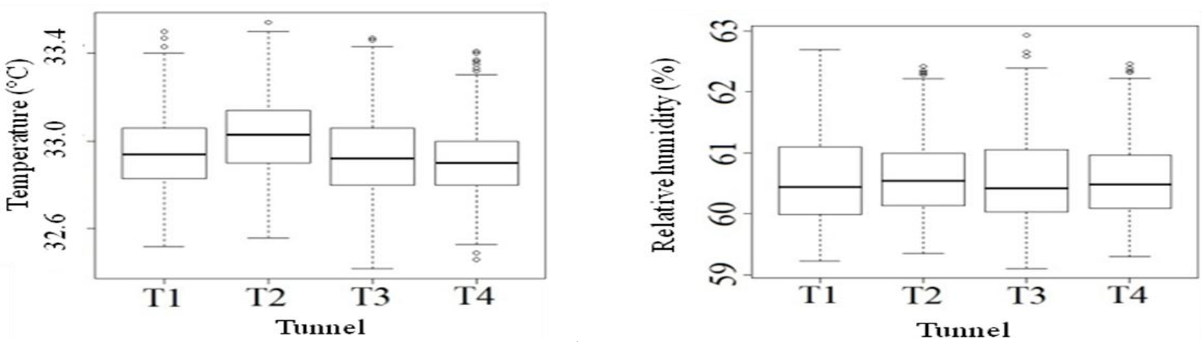
Set point at 27°C Set point at 60%

C.



Set point at 30°C Set point at 60%

D.



Set point at 33°C Set point at 60%

Figure 6. Boxplots for the temperatures of 24 (a), 27 (b), 30 (c) and 33 °C (d) and relative humidity at 60% for each wind tunnel (T1, T2, T3 and T4)

The values obtained for the air velocity inside the wind tunnel are shown in Table 2.

Table 2. Values observed for the air velocity in the transversal session of the cage located inside the wind tunnels

	Air velocity (m s^{-1})			
Tunnel	average ± sd	medium	minimum	maximum
1	0.48 ± 0.05	0.50	0.30	0.60
2	0.48 ± 0.04	0.50	0.40	0.60
3	0.47 ± 0.05	0.50	0.30	0.60
4	0.48 ± 0.05	0.50	0.30	0.60

sd: standard deviation

From Figure 7, it is observed that the response time for the air temperatures inside the wind tunnel reached previously established values (set points) were 19 min 10 s, 20 min 10 s, 17 min 00 s 30 min 00 s and, at temperatures of 24, 27, 30 and 33 °C, respectively.

The variations of the temperatures of the external environment and in the interior of the room where the tunnels were located, for the previously mentioned set point values, were 29.95 ± 2.8 °C and 22.28 ± 0.54 °C, 30.83 ± 2.68 °C and 23.91 ± 0.59 °C, 30.13 ± 2.28 °C and 25.13 ± 0.59 °C, 28.38 ± 2.28 °C and 27.05 ± 1.22 °C.

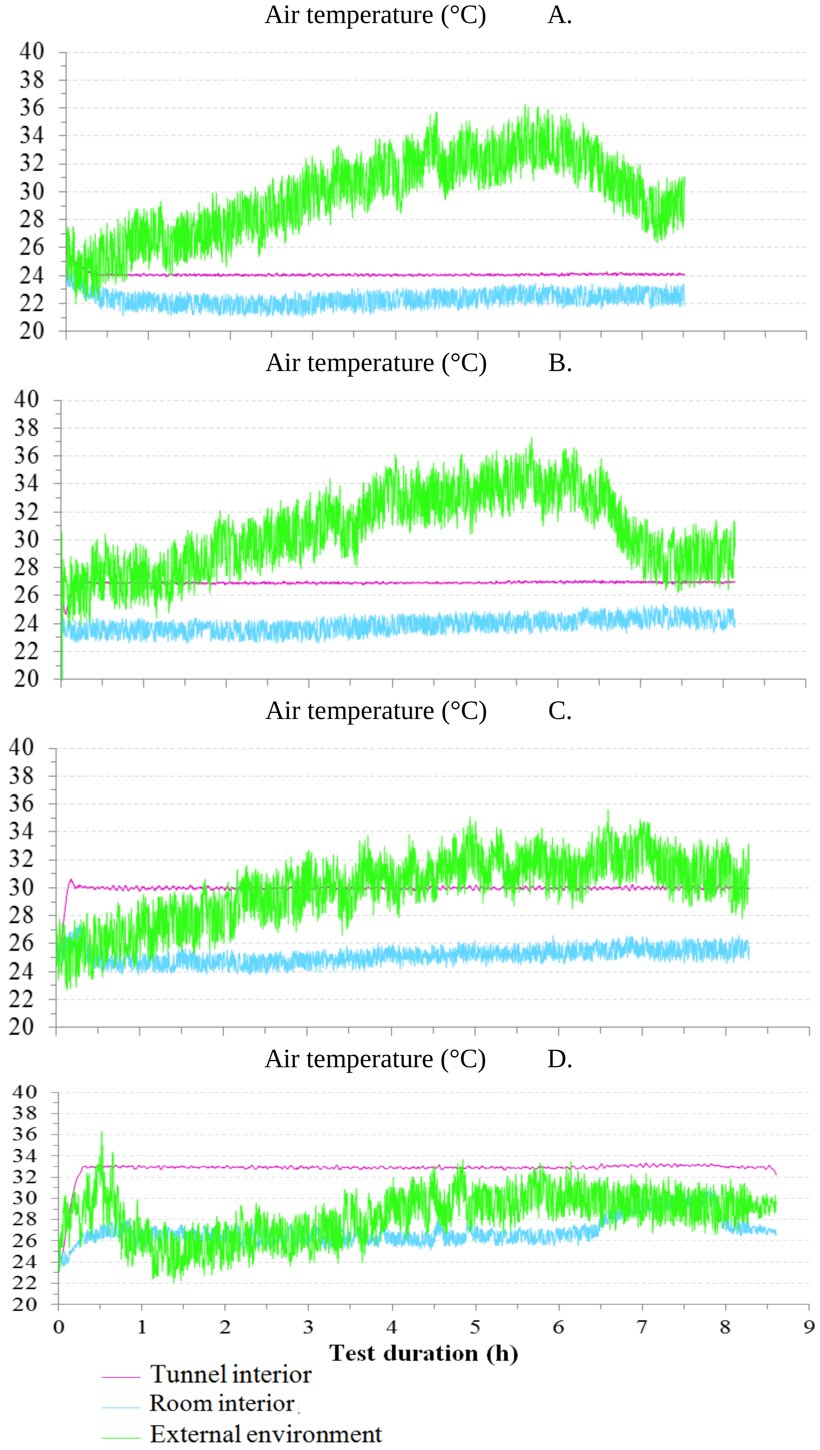


Figure 7. Behavior of the air temperature inside the wind tunnel, inside the room and in the external environment for the set points at 24 (a), 27 (b), 30 (c) and 33 °C (d)

Video images captured inside the wind tunnel by IP cameras (Figures 8A and 8B) allow the development of studies related to animal behavior (Cordeiro, 2007). In turn, the infrared images (Figures 8C and 8D) allow the monitoring of the animal surface temperature, allowing the conduction of researches involving only the evaluation of this animal's response, the study of direct evaporative cooling (Yanagi Junior et al., 2002) and, the validation of models based on equations of heat and mass transfer.

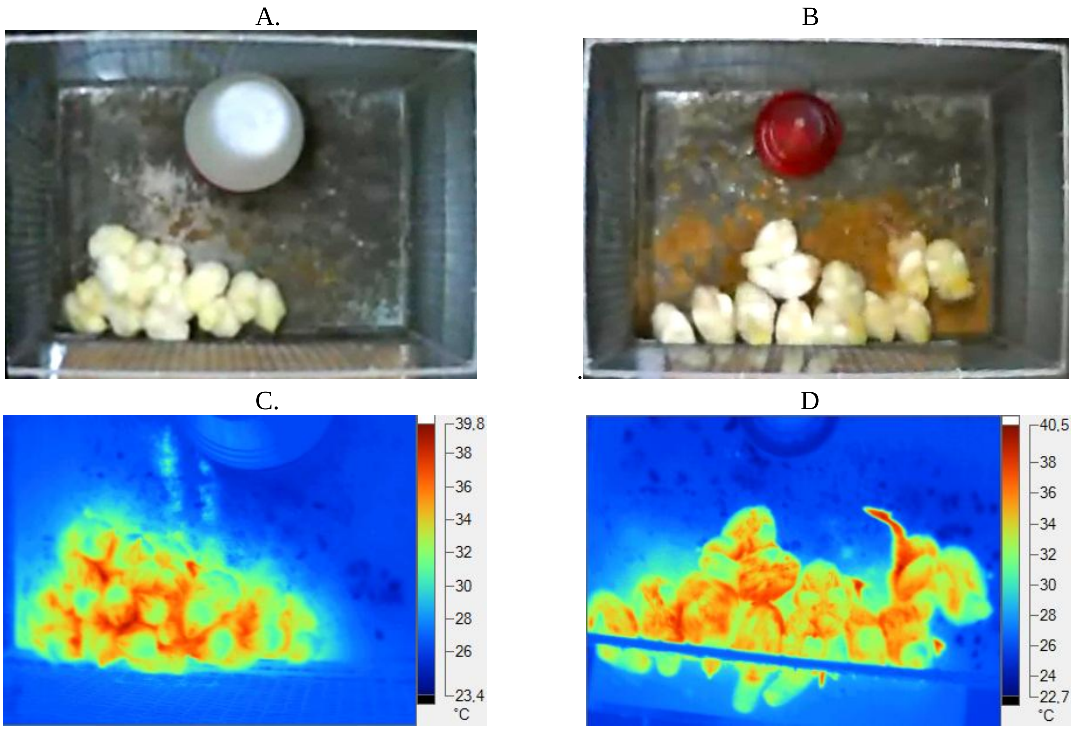


Figure 8. Video (A and B) and infrared (C and D) images captured inside the wind tunnels, for the temperatures at 24 ºC (A and C) and 30 ºC (B and D), and, relative humidity at 60 %

IV. CONCLUSIONS

A system for acquisition, storage and control of data was developed for studies on the interaction between thermal conditions and physiological responses of small animals. It was found that the system showed deviations of ± 0.19 °C ± 0.75% and ± 0.05 m s^{-1} for t_{air}, RH and V, respectively, when comparing the values measured inside the tunnels to those previously established (set points).

V. AKNOWLEGDMENTS

The authors thank CAPES, CNPq and FAPEMIG for the financial support given to the project.

LITERATURE CITED

[1] Cordeiro, M. B. *Análise de imagens na avaliação do comportamento, do bem-estar e do desempenho de pintos de corte submetidos a diferentes sistemas de aquecimento.* 2007. 121 p. Tese (Doutorado em Engenharia Agrícola – Construções Rurais e Ambiência) – Universidade Federal de Viçosa, Viçosa, 2007.

[2] Damasceno, F. A.; Yanagi Junior, T.; Lima, R. R.; Gomes, R. C. C.; Moraes, S. R. P. *Avaliação do bem-estar de frangos de corte em dois galpões comerciais climatizados.* Ciência e Agrotecnologia, Lavras, v.34, n.4, p.1031-1038, jul./ago. 2010. <http://dx.doi.org/10.1590/S1413-7054201 0000400033>. 21 Jun. 2012.

[3] Ferreira, F.; Campos, W. E.; Carvalho, A. U.; Pires, M. F. A.; Martinez, M. L.; Silva, M. V. G. B.; Verneque, R. S.; Silva, P. F. *Parâmetros clínicos, hematológicos, bioquímicos e hormonais de bovinos submetidos ao estresse calórico.* Arquivo Brasileiro de Medicina Veterinária e Zootecnia, Belo Horizonte, v.61, n.4, p.769-776, ago. 2009. <http://dx.doi.org/10.1590/S0102-09352009 000400002>. 05 Set. 2011.

[4] Kiefer, C.; Meignen, B. C. G.; Sanches, J. F.; Carrijo, A. S. *Resposta de suínos em crescimento mantidos em diferentes temperaturas.* Archivos de Zootecnia, Córdoba, v.58, n.221, p.55-64, mar. 2009. <http://dx.doi.org/10.4321/S0004-05922009 000100006>. 15 Jun. 2012.

[5] Maia, A. S. C.; Silva, R. G.; Andrade, P. C. *Efeitos da temperatura e da movimentação do ar sobre o isolamento térmico do velo de ovinos em câmara climática.* Revista Brasileira de Zootecnia, Viçosa, v.38, n.1, p.104-108, jan. 2009. <http://dx.doi.org/10.1590/S1516-35982009000100014>. 21 Jul. 2012.

[6] Oba, A.; Souza, P. A.; Souza, H. B. A.; Leonel, F. R.; Pelicano, E. R. L.; Zeoula, N. M. B.; Bolelli, I. C. *Qualidade da carne de frangos de corte submetidos a dietas suplementadas com crômio, criados em diferentes temperaturas ambientais.* Acta Scientiarum. Animal Sciences, Maringá, v.29, n.2, p.143-149, 2007. <http://eduemojs.uem.br/ojs/index.php/ActaSciAnimSci/article/view/218/170>. 07 Ago. 2011.

[7] Oliveira Neto, A. R. O.; Oliveira, R. F. M.; Donzele, J. L.; Barreto, S. L. T.; Vaz, R. G. M. V.; Gasparino, E. *Níveis de metionina + cistina total para frangos de corte de 22 a 42 dias de idade mantidos em ambiente termoneutro.* Revista Brasileira de Zootecnia, Viçosa, v.36, n.5, p.1359-1364, set./out. 2007. <http://dx.doi.org/10.1590/S1516-35982 007000600019>. 14 Set. 2011.

[8] Oliveira, W. P.; Oliveira, R. F. M.; Donzele, J. L.; Gomes, P. C.; Martins, M. S.; Assis, A. P. *Redução do nível de proteína bruta em rações para frangos de corte em ambiente de estresse por calor.* Revista Brasileira de Zootecnia, Viçosa, v.39, n.5, p.1092-1098, maio 2010. <http://dx.doi.org/10.1590/S1516-35982010000500020>. 20 jul. 2012.

[9] Pereira, D. F.; Bighi, C. A.; Gabriel Filho, L. R.; Gabriel, C. P. C. *Sistema fuzzy para estimativa do bem-estar de matrizes pesadas.* Engenharia Agrícola, Jaboticabal, v.28, n.4, p.624-634, out./dez. 2008. <http://dx.doi.or g/10.1590/S0100-69162008 000400002>. 15 Out. 2011.

[10] Pereira, D. F.; Salgado, D. D.; Nääs, I. A.; Penha, N. L. J.; Bighi, C. A. *Efeitos da temperatura do ar, linhagem e período do dia nas frequências de ocorrências e tempos de expressão comportamental de matrizes pesadas.* Engenharia Agrícola, Jaboticabal, v.27, n.3, p.596-610, set./dez. 2007. <http://dx.doi.org/10.1590/S0100-69162007000400002>. 27 Jan. 2012.

[11] Sanches, J. F.; Kiefer, C.; Moura, M. S.; Silva, C. M.; Luz, M. F.; Carrijo, A. S. *Níveis de ractopamina para suínos machos castrados em terminação e mantidos sob conforto térmico.* Ciência Rural, Santa Maria, v.40, n.2, p.403-408, fev. 2010. <http://dx.doi.org/10.1590/S0103-84782009005000257>. 25 Jan. 2012.

[12] Silva, E. A.; Kiefer, C.; Moura, M. S.; Bünzen, S.; Santos, A. P.; Silva, C. M.; Nantes, C. L. *Duração da suplementação de ractopamina em dietas para leitoas em terminação mantidas sob alta temperatura ambiente.* Ciência Rural, Santa Maria, v.41, n.2, p.337-342, fev. 2011. <http://dx.doi.org/10.1590/S0103-84782011005000001>. 17 Jun. 2012.

[13] Silva, V. K.; Silva, J. D. T.; Gravena, R. A.; Marques, R. H.; Hada, F. H.; Moraes, V. M. B. *Desempenho de frangos de corte de 1 a 21 dias de idade alimentados com rações contendo extrato de leveduras e prebiótico e criados em diferentes temperaturas.* Revista Brasileira de Zootecnia, Viçosa, v.38, n.4, p.690-696, abr. 2009. <http://dx.doi.org/10.1590/S1516-35982009000400015>. 22 Mar. 2012.

[14] Siqueira, J. C.; Oliveira, R. F. M.; Donzele, J. L.; Cecon, P. R.; Balbino, E. M.; Oliveira, W. P. *Níveis de lisina digestível da ração e temperatura ambiente para frangos de corte em crescimento.* Revista Brasileira de Zootecnia, Viçosa, v.36, n.6, p.2054-2062, 2007 (supl.). <http://dx.doi.org/10.1590/S1516-35982007000900015>. 05 Set. 2011.

[15] Yanagi Junior, T.; Xin, H.; Gates, R. S. *A research facility for studying poultry responses to heat stress and its relief.* Applied Engineering in Agriculture, v.18, n.2, p.255-260, 2002. <http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1143&context=abe_eng_pubs>. 12 Out. 2010.