ENCIT 2018

17th Brazilian Congress of Thermal Sciences and Engineering
November 25th-28th, 2018, Águas de Lindóia, SP, Brazil

ENCIT-2018-1
SIMULATION OF THE AIR FLOW AND HEAT TRANSFER INSIDE AN AVIARY FOR BROILERS PRODUTION

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Abstract. *This work has the purpose of evaluating the temperature and air velocity distribution in a standard aviary model used for the production of chicken meat using computational fluid dynamics (CFD). The results showed that the heat transfer inside the aviary is not uniform. Heat transfer is disadvantageous in the lowest velocity regions, where the highest temperatures are located. The proposal to change ventilation system configuration, modified the airflow, increasing the uniformity of temperatures inside the aviary, and reducing the magnitude of high temperature regions. These results allow to conclude the proposed configuration minimizes the temperature gradient formed in the flow, besides increasing the region for distribution of broilers inside the aviary, improving the thermal comfort of the place.*

Keywords: *thermal comfort; heat transfer; temperature profile; air velocity, SWFS.*

1. INTRODUCTION

The broilers thermal comfort is an important variable to be controlled during the whole productive cycle of these animals. Studies related to zoo technical indexes influenced by broilers thermal comfort have been developed in the literature by Cândido *et al*. (2016), Souza *et al*. (2014), Cassuce *et al*. (2013), Almeida and Passini (2013), Souza *et al*. (2011), Rocha *et al*. (2010), Welker *et al*. (2008), Oliveira *et al*. (2006), May and Lott (2000), Cheng, Hamre and Conn (1997), Weeks, Webster and Wild (1996).

Conditions involving the environment configuration to chickens thermal comfort were presented in studies of Campos *et al*. (2013), Cordeiro *et al*. (2010), Furtado *et al*. (2010), Menegali *et al*. (2013). There are few studies in the literature that explore conditions related to air flow and heat transfer in the environment.

Nascimento (2011) points out several factors that are influenced by temperature and ventilation, such as feed conversion. The broilers thermal comfort can generate negative effects on their performance. When broilers are in an environment within the ranges of their thermal comfort, maximum feed conversion is achieved, reducing the time required for slaughter. Consequently, the cycle between batches is reduced, meat quality is improved and production costs are reduced due to increased productivity.

Computational Fluid Dynamics (CFD) is a tool used to study fluid flow and heat transfer through computational simulations. Research using CFD in the most varied areas has been carried out by Mei *et al*. (2018), Busto *et al*. (2018), Wang *et al*. (2017), Delgado *et al*. (2017), Turner *et al*. (2017), Bianchi *et al*. (2017), Lorusso *et al*. (2017), Prah and Yun (2017).

Several software and numerical methods can be used in computational simulations. SolidWorks Flow Simulation (SWFS) is an integrated CFD based software that uses the finite volume method (FVM) for problem solving and has been applied in fluid flow and heat transfer analysis (Shrikant *et al*., 2016, Driss *et al*., 2014, Ragoth Singh and Nataraj, 2014).

In this context, this work has objective of evaluating the air flow and the heat transfer inside aviaries for broilers production, using computational fluid dynamics, through SWFS. It is analyzed at simulation, the velocity and temperature profile inside an aviary with a standard configuration and with real boundary conditions. Later, a new configuration is proposed, seeking better results to heat transfer, in order to provide an environment with better thermal comfort for broiler rearing.

2. METHODOLOGY

The work encompasses internal air flow and heat transfer study, in a broiler aviary through simulation using computational fluid dynamics (CFD).

2.1 Environment characterization

Modern aviaries can vary from 90 m up to 165 m in length, with widths varying from 12 m up to 18 m (go free) and height approximately 2.30 m (right foot). The materials used for insulation are polypropylene / polyethylene tarpaulins on the sides and lining, walls on the front and walls 0.6 m high on the ground on the sides. The most used roofs are asbestos cement tiles.

The air conditioning system counts on exhaust fans and with evaporative cooling system, thus creating an air tunnel in the shed. The air conditioning system must meet the thermal comfort temperatures of broilers as recommended by Cassuce *et al*. (2013).

Camargo (2003-2004) indicates in order to decrease the ambient temperature, evaporative cooling is widely used and is based on the waters evaporating process, which constitutes a change of physical state that consumes energy, and this energy is withdrawn from the air. Generally, large fans are used and a corrugated cellulose board moistened by where the outside air passes. Camargo (2003-2004) also points out that heat and mass transferred between air and water reduce the air dry bulb temperature and increase its humidity, keeping the enthalpy constant, characterizing the adiabatic cooling.

The main heat transfer phenomena that influence the temperature inside the aviary are conduction, convection and radiation.

2.2 Mathematical modeling

For convection study, which is the main type of heat exchange at this environment, Braga Filho (2004) points out that one of the most important steps is to determine if the boundary layer is laminar or turbulent. It is possible to identify flow regime through the Reynolds number, given by Eq. (1).

$$\mathrm{Re}_x = \frac{\rho \cdot u_\infty \cdot x}{\mu} \quad (1)$$

ρ is the fluid specific mass (kg.m^{-3}), u_∞ is the fluid velocity in the distance (m.s^{-1}), μ is the dynamic viscosity (Pa.s) e x is the characteristic length (m).

For the determination of fluid velocity profile, Çengel (2015) points out that an element can pass through four fundamental types of movement or deformation: translation, rotation, linear deformation and shear deformation. These combined motions can be represented by the Navier Stokes equation, Eq. (2).

$$\rho \cdot \frac{\mathrm{D}\vec{\mathrm{V}}}{\mathrm{Dt}} = -\vec{\nabla} P + \rho \cdot \vec{g} + \mu \cdot \nabla^2 \vec{V} \quad (2)$$

g is the gravity acceleration (m.s^{-2}) e ∇P is the pressure gradient in all directions and $\nabla^2 V$ is the Laplacian of velocity.

For finite volume method, Maliska (2004) and Incropera *et. al*. (2008) point out that it starts from the simple form of an energy balance assuming that all the thermal flows are directed into a nodal point, according to Eq. (3).

$$\dot{E}_{ent} + \dot{E}_g = 0 \quad (3)$$

$\dot{E}_{ent}$ is the energy that input into control volume, $\dot{E}_g$ is the energy generated in the control volume.

2.3 Data collection and computational model

In order to approximate the temperature distribution and real velocity in the aviary, simulation by finite elements method of air flow and heat transfer was performed, adopting the estimated real boundary conditions *in loco*. The software used for analysis was SolidWorks Flow Simulation, version 2015.

The estimated temperatures used as boundary conditions are 26 °C for air at evaporative plate's entrance, temperature measured with thermometer at the air input.

The side walls are composed by brick and a thin polythene curtain which is minimally resistant to heat exchange. Accordingly, the sidewall temperature is approximately the external temperature of 31.8 °C.

Exhausters are located at aviary's air output, thus working with negative pressure to perform ventilation in the enclosure. The pressure exerted by each exhauster can be approximated by the exhausters performance curves recently supplied by Munters (2017) at a value of -50 Pa at exhauster input.

The front and back walls are composed solely of masonry. Thus, using the global heat transfer coefficient according to Silva (2003), the heat flux is approximately 4.5 $W.m^{-2}$.

The lining boundary condition is composed of a thin polythene canvas (same material as the curtains). Thus, in the same way as for the curtains, it is appreciated that the thickness thereof is very thin, providing negligible heat transfer resistance. Consequently, the temperature of 33 °C, which is the approximate temperature of the air pocket formed between the roof and the liner, will be maintained for the ceiling boundary condition.

On the surface where broilers are, a heat flux of 120 $W.m^{-2}$ was estimated, which is approximated to the human metabolism (240 $W.m^{-2}$) and that broilers mass in 2 m^2 corresponds to a person mass.

Mesh element adopted has a maximum size of 1.23 m x 1.15 m x 1.09 m, with a prismatic rectangular model, because of environment large dimensions (90 m x 16 m x 2.3 m) minimizing the computational effort without large deviations from the study.

Flow was studied in its stationary condition, because the phenomenon of heat transfer and flow inside the aviary at conditions listed above are constant, being out of boundary conditions / atypical phenomena.

The eight exhausters were present represented in their actual form, in a circular format with a diameter of 1.5 m and arranged in the back of the aviary. Thus, two exhaust regions with 4 exhausters each were represented.

Simulations were performed in the configuration described above for standard model. Subsequently, the simulation was performed with proposed configuration, putting exhausters and evaporative plates in opposite sides. To maintain the same average flow rate, the total number of exhausters was increased to 16. The boundary conditions remained the same as the current configuration.

Fig. 1 shows the outline of aviary configuration in standard model and Fig. 2 in the proposed configuration.

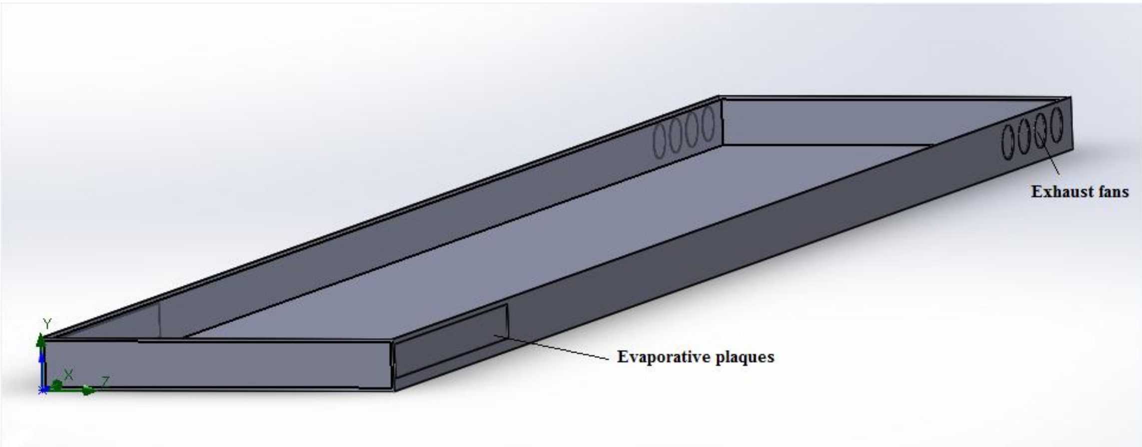

Figure 1: Aviary configuration at standard model

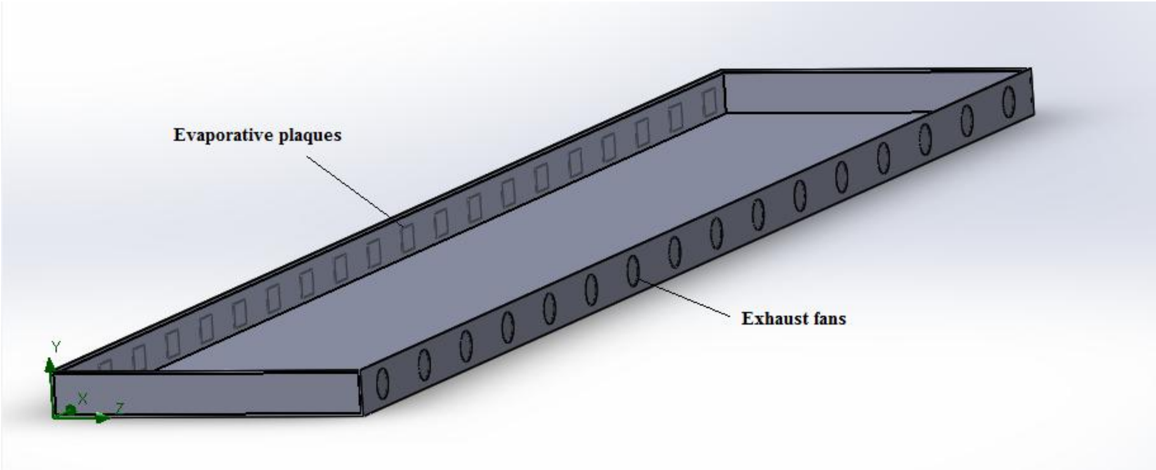

Figure 2: Aviary configuration at proposed model

3. RESULTS

3.1 Simulation at standard model

The results for temperature profile and air velocity profile inside the aviary are shown in Fig. 3 and Fig. 4, respectively.

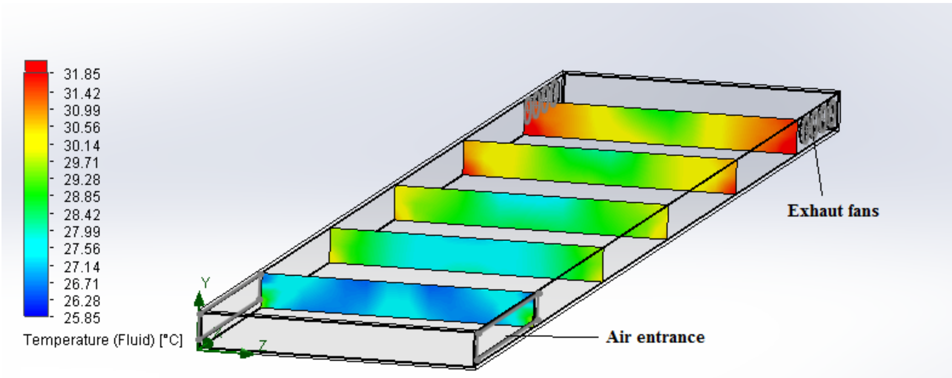

Figure 3: Temperatures distribution along the aviary

In Fig. 3, it can be seen that temperatures distribution inside aviary is not uniform. It is observed that lower temperatures are located at central region and near the air inputs. As air approaches the exhaust region and the sides, temperature increases, providing a temperature gradient of 6.2 °C inside the environment.

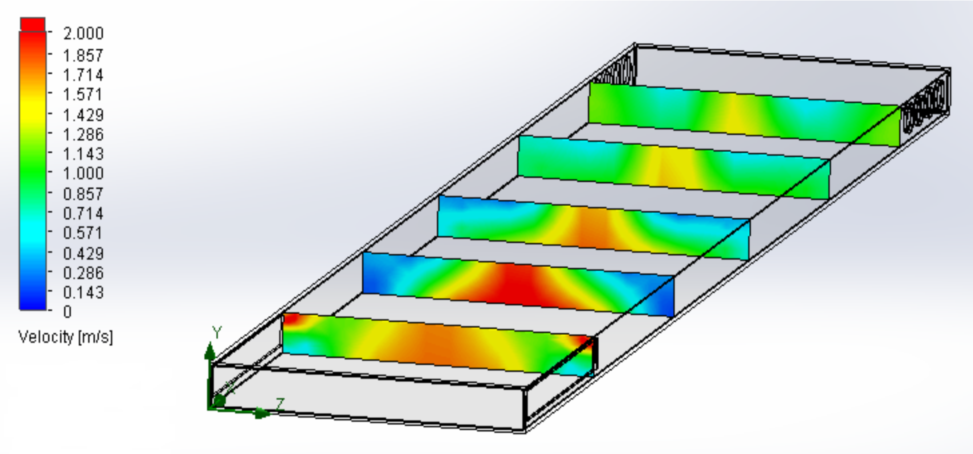

Figure 4: Velocity distribution along the aviary

It can be seen in Fig. 4 that higher air velocities are in central region and near the air inputs. Therefore, in regions with higher air velocities, the lower temperatures are concentrated, due to the higher convection heat exchange in these regions. Consequently, these sites are more suitable for broilers thermal comfort in the current configuration, which tends to cause broilers crowding in these places, increasing the lesions rate and animals death.

In studies developed by Zeferino (2016), Merlier *et al*. (2015), Aghabozorg, Rashidi and Mohammadi (2015), Ateeque *et al*. (2014) it was observed that heat transfer convective coefficient is directly proportional to the increase of fluid's flow velocity. This indicates that results found are in accordance with literature, since the convection heat transfer rate by is directly proportional to heat transfer coefficient.

3.2 Simulation at proposed model

By performing changes described in the environment configuration, we obtained temperature distribution shown in Fig. 5 and air velocity profile shown in Fig. 6.

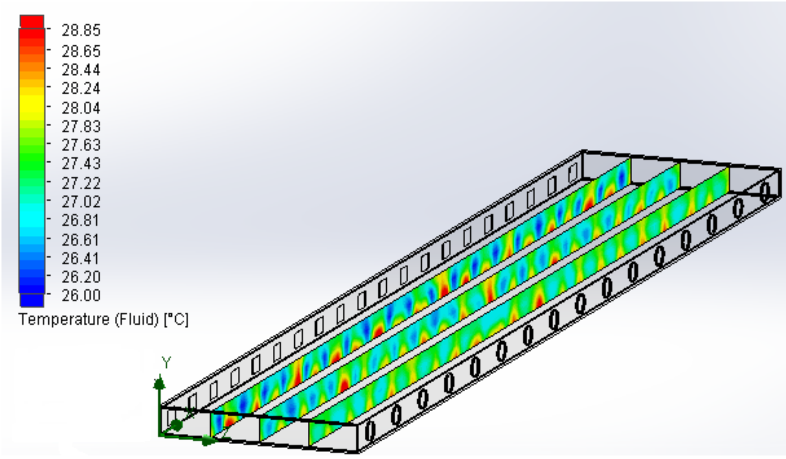

Figure 5: Temperature distribution at proposed model

Analyzing the results of proposed model, there was an increase in the uniformity of temperature distribution (Fig. 5) in most of environment, resulting in a temperature gradient of 2 °C, equivalent to approximately 67.7% reduction. In addition, the magnitude of higher temperature reduced by 2.85 °C.

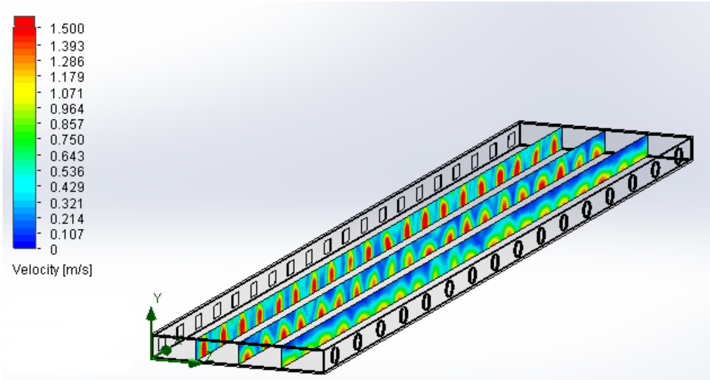

Figure 6: Velocity distribution at proposed model

By analyzing air velocity profile (Fig. 6), it can be seen that near air inputs are located the highest velocities (1.5 m.s^{-1}). In the region near to exhaustion, velocity decreases (0.8 m.s^{-1}). In the region away from the current lines, air velocity is practically zero. Comparing with standard model, it is possible to notice that in height levels closer to the ground, the velocity at proposed model are larger, favoring the heat exchange and temperatures reduction observed in Fig. 5. It is also possible to observe that the region where heat transfer is favored is higher at proposed model than standard model, which may reduce crowding sites and loss of animals during confinement.

4. CONCLUSION

The study of proposed air flow showed a reduction of approximately 67.7% in the temperature gradient inside the environment and provided higher velocities at points closer to broilers.

Therefore, aiming for higher temperature uniformity at aviary, new configuration favors heat transfer inside the environment, indicating that proposed configuration can be an alternative for improvement of the place climatization, and consequently, can provide a greater thermal comfort to broilers.

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6. ACKNOWLEDGMENTS

Thanks to Universidade Comunitária da Região de Chapecó – UNOCHAPECÓ for the support to carry out this work.

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