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EVALUATION OF CLIMATE CONTROL STRATEGIES IN RABBIT HOUSES

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ABSTRACT

Productive and health traits, animal welfare, and environmental pollution factors are strongly affected by environmental conditions. Therefore, achieving optimal conditions for animals in terms of environmental conditions is crucial. In order to achieve the highest level of well-being for rabbits, the main factors that must be controlled are: temperature, relative humidity, air velocity, and gas concentrations (mainly ammonia and carbon dioxide). Among all tools available to control, the key factor is ventilation rate. The main aim of this paper is to provide a clear methodology to determine ventilation rates in rabbit buildings to achieve optimal environmental conditions. In addition, different ventilation designs will be evaluated in terms of air velocity and distribution profiles. To this aim, ventilation rate requirements were calculated following four criteria (controlling temperature, relative humidity, carbon dioxide, and ammonia concentrations) for a whole year in a given location (Castellón, Spain) for both fattening rabbits and reproducing does. Air velocity patterns and velocities were studied in four structures considered as being representative of typical rabbit buildings using computational fluid dynamics. One of them was naturally ventilated while the other three were considered as mechanically ventilated buildings. For the given conditions, the maximum ventilation rate requirements occurred at the end of autumn, while there was other peak during summer. In general, the control of humidity is the most restrictive criteria, followed by ammonia concentration control. Regarding the air velocity patterns in buildings, naturally ventilated buildings, as well as cross-flow and chimney mechanically ventilated buildings, presented a more homogeneous distribution. The position of sidewall inlets had a strong effect on the air velocity profiles at animals' level, being a potential tool to reduce heat stress in warm climates.

Key words: Rabbits, ventilation rate, climate control, air velocity, air distribution.

INTRODUCTION

One of the main management tools for rabbit farmers is environmental control in buildings. Achieving optimal conditions for animals in terms of environmental conditions is crucial. Productive and health trait performance, animal welfare, and even environmental pollution factors are strongly affected by environmental conditions (CIGR, 1992). In order to achieve the highest level of well-being for rabbits, the main factors that must be controlled are: temperature, relative humidity (RH), air velocity, gas concentrations (mainly ammonia and carbon dioxide), and microbial concentrations in air. Among these factors, temperature is the one with a greatest effect from a productive point of view (Marai *et al.*, 2002). On the one hand, if temperature in the building exceeds the optimal limits for the animals, they use part of their energy intake for thermoregulation, leading to higher food consumption levels up to 10% (Cervera and Fernández Carmona, 1998). On the other hand, reproductive abilities are also affected if temperature is not optimal. Fertility, litter size, and milk production are reduced, while kit mortality increases (Frangiadaki *et al.*, 2003; Marai *et al.*, 2002). The effects of other environmental factors on rabbits have not been widely studied. Nevertheless, it is known that RH has a close relationship with temperature, whereby increasing the heat feeling of animals occurs at high temperatures when RH increases. High values for RH also favour the proliferation of microorganisms, while too low of values increase respiratory and digestive problems (Villagrá *et al.*, 2004). Air velocity is also relevant since rabbits are quite sensitive to air streams, therefore maintaining a proper air velocity at animal's level is crucial in rabbit buildings. Finally, despite a paucity of reports on threshold gas and PM concentrations, it is well known that exposure to high ammonia concentrations has a strong negative effect on both productive and reproductive traits in rabbits (Sahuquillo *et al.*, 2004). To determine optimal environmental conditions in livestock buildings, a number of tools can be used. Those tools could be classified according to their nature in four main groups: ventilation, isolation, heating, and cooling systems. Among them, ventilation is the main factor since it can be used to control all traits described above (CIGR, 1992). The main aim of this paper is to provide a clear methodology to determine ventilation rates in rabbit buildings to achieve optimal environmental conditions. In addition, different ventilation designs will be evaluated in terms of air velocity and distribution profiles.

MATERIALS AND METHODS

Ventilation rate determination

As previously stated, the optimal ventilation rate depends on temperature, relative humidity, and carbon dioxide and ammonia concentrations. A proper ventilation rate should be designed to prevent inadequate environmental conditions inside the building. Therefore, ventilation rates should be calculated considering these four factors. Ultimately, the highest ventilation flow will be chosen to account for the most restrictive factor.

Equation 1 summarizes the methodology to calculate the ventilation rate needed to control the temperature in the building.

$$V_{Temperature}\left(m^3\cdot h^{-1}\right)=\frac{Q_{sa}+Q_{sb}}{H_s\times\left(t_i-t_o\right)}\times v_s$$

Equation 1

Where, $V_{Temperature}$ is the ventilation rate needed to eliminate excess heat (m^3/h), Q_{sa} represents the sensible heat transmitted through the building enclosures (kcal/h), Q_{sb} is the sensible heat produced by animals (kcal/h), H_s is the specific heat of air (kcal/Kg·ºC), t_i and t_o are inside and outside temperatures (ºC), respectively, and v_s is the specific volume of air (m^3/kg air). The amount of sensible heat produced by rabbits can be calculated as a function of their metabolic weight, following CIGR (2002) recommendations that are summarized in Table 1. In contrast, the amount of sensible heat transmitted through the building enclosures will depend on their isolation and surface, as well as the difference between inside and outside temperatures (Garcimartin et al., 2007).

To obtain the optimal ventilation rate to maintain humidity at desired limits, Equation 2 must be used.

$$V_{H_2O}\left(m^3\cdot h^{-1}\right)=\frac{Q_l}{597\times\left(w_i-w_o\right)}\times v_s$$

Equation 2

Where, V_{H2O} is the ventilation rate needed to control humidity (m^3/h), Q_l is the latent heat production in the building (kcal/h), w_i and w_o are inside and outside air absolute humidity (kg water vapour/kg dry air), respectively, and *597* is the energetic value of water vapour (kcal/kg water vapour). Latent heat production is also related to animals' weight as shown in Table 1. It is also important to bear in mind that absolute humidity can be determined by considering both air temperature and relative humidity.

Regarding the control of gas concentrations, Equation 3 provides the methodology to determine the minimum ventilation rate to control carbon dioxide and ammonia concentrations.

$$V_{GAS}\left(m^3\cdot h^{-1}\right)=\frac{E_{GAS}}{GAS_{\max}-GAS_{out}}$$

Equation 3

Where, V_{GAS} is the ventilation rate needed to control gas (CO_2 or NH_3) concentration (m^3/h), E_{GAS} is the gas emission (mg/h), GAS_{max} is the maximum gas concentration admissible for animals (mg/m), and GAS_{out} the gas concentration of external air (mg/m). Table 1 also provides the emission rates for both gases according to Calvet *et al.* (2011) and Estellés *et al.* (2010).

Table 1: Sensible and latent heat production, carbon dioxide and ammonia emissions from rabbits

Animal category	Q_s kcal/h and animal[1]	Q_l kcal/h and animal[1]	E_{CO2} g/h and animal[2,3]	E_{NH3} mg/h and animal[2]
Fattening Rabbits	4.4	2.6	4.2	10.1
Rabbit does	8.6	5.1	11.0	55.9

[1]CIGR (2002) [2], Calvet *et al.* (2011) [3], and Estellés *et al.* (2010).

These equations were applied in a practical situation to obtain ventilation rates requirements per animal under two theoretical rabbit building simulations, one for fattening rabbits and other one for does, during one year. Some assumptions were made in order to determine ventilation rates: i) both buildings were located in SE of Spain (Castellón), and normal meteorological data from the Spanish Agency of Metetorology was used to define outside environmental conditions (www.aemet.es/en/serviciosclimaticos/datosclimatologicos/valoresclimatologicos?l=8500A&k=val), ii) target temperatures in the building were 18 ºC in winter and 25 ºC in summer, while RH was fixed between 65 and 70%, iii) maximum gas concentrations in the building were fixed at 5,400 and 7 mg/m^3 for CO_2 and NH_3, respectively, and iv) sensible heat transmission through building enclosures was set at 0.3 and 2.9 kcal/h animal for fattening rabbits and does, respectively.

Air velocity patterns

Air velocity patterns and velocities were studied in simulations for four structures considered as representative of typical rabbit buildings. One of them was naturally ventilated, while the other three were considered as mechanically ventilated buildings. A front view of all four models is shown in Figure 1.

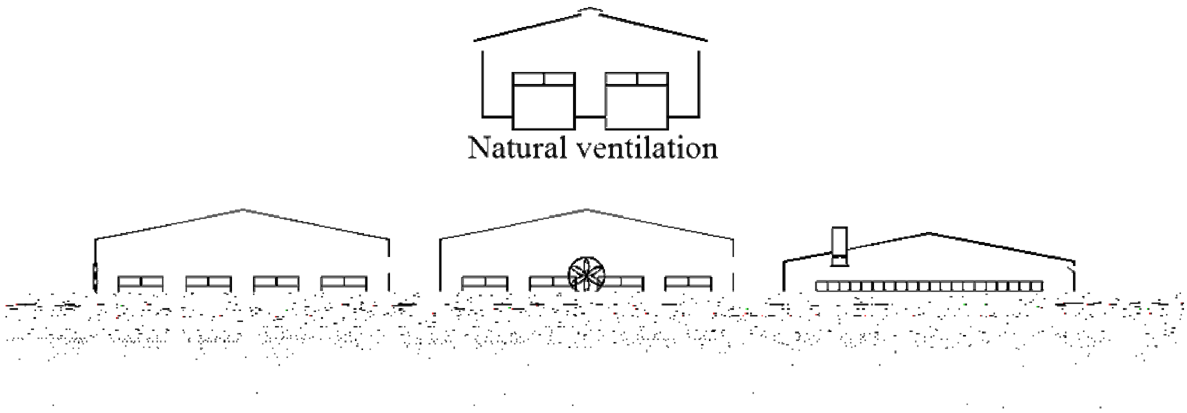

Figure 1: Front view scheme of the modeled rabbit houses

The position of air inlets was also evaluated in the naturally ventilated building and the cross-flow mechanically ventilated one. Airflow patterns were evaluated in two conditions: a) upper air inlets and b) lower air inlets. Computational fluid dynamics (CFD) was used to determine air patterns inside the buildings. The software Ansys Fluent ® was used to this aim.

RESULTS AND DISCUSSION

Ventilation rate determination

Monthly average ventilation rates requirements for fattening rabbits and does, calculated considering all previously methodologies, are shown in Figure 2.

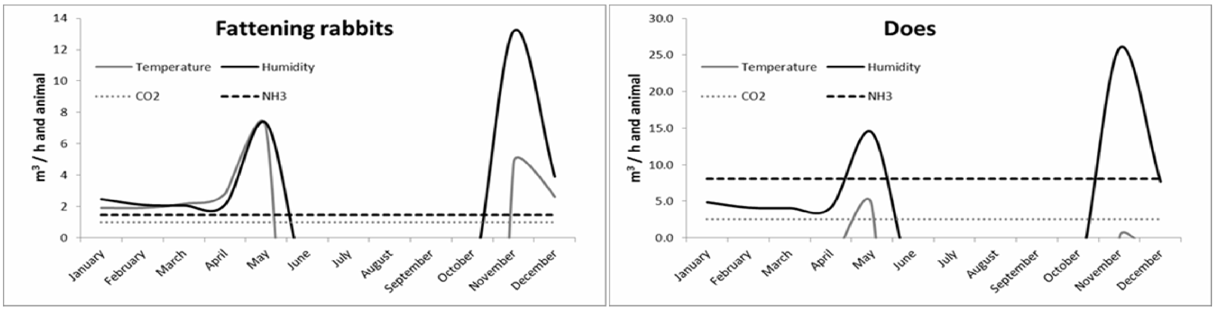

Figure 2: Monthly average ventilation rate requirement following different calculation criteria for fattening rabbits and does in Castellón (Spain)

As can be observed from the above figure, ventilation rate needs were highly variable during the year. For the given conditions, the maximum requirements occurred surprisingly at the end of autumn, while there was another peak in summer. In general, the control of humidity was the most restrictive criteria, followed by ammonia concentration control. These two factors are normally not considered when determining and operating ventilation control in practice.

Air velocity patterns

Figure 3 shows air velocity profiles for a naturally ventilated building, considering upper and lower inlets.

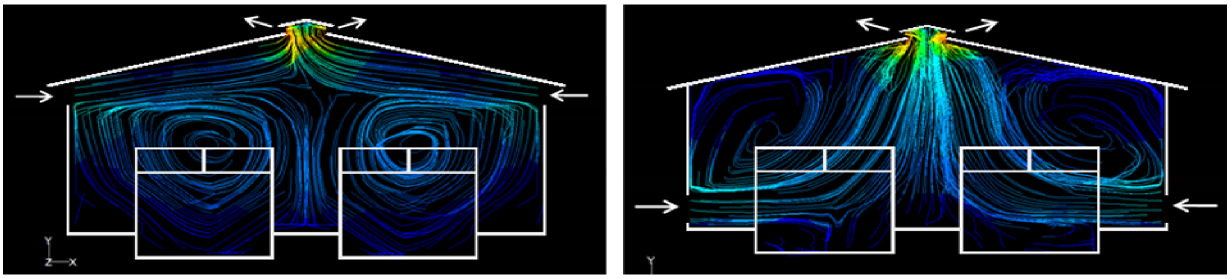

Figure 3: Air velocity profiles in a naturally ventilated building with upper inlets (left) and lower inlets (right). Air velocity follows an increasing color scale from blue (low) to red (high).

Air distribution in naturally ventilation buildings with ridge vents was homogeneous according to our models. Higher air velocities at animals' level were found when wall inlets were located at the bottom, which might be a potential tool for hot climates. Orientation of the building in relation to wind direction also has a strong effect on air distribution (data not shown), as reported by Ogunjimi *et al.* (2007).

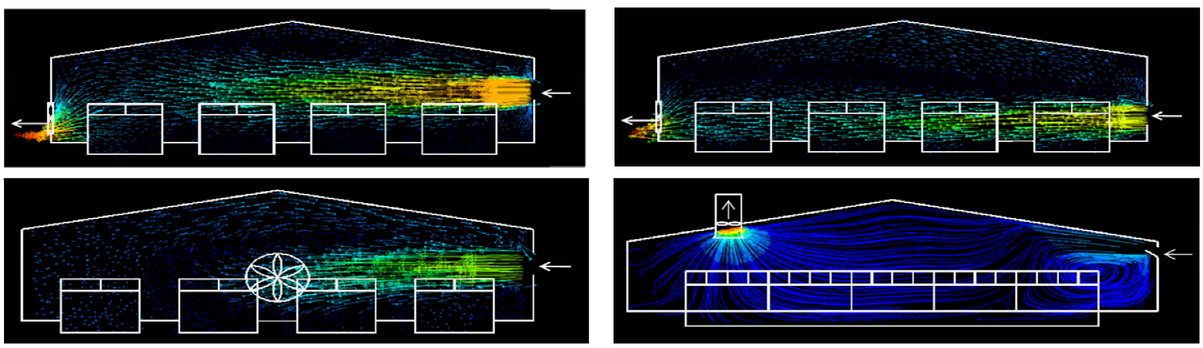

Figure 4: Air velocity profiles in mechanically ventilated buildings. Above drawings represent cross-flow ventilations with upper (left) and lower inlets (right). Tunnel ventilation is depicted in the bottom left and chimney ventilation in the bottom right. Air velocity follows an increasing color scale from blue to red.

Regarding mechanically ventilated buildings, Figure 4 presents the results obtained using CFD models. As expected, higher air velocities were found than for naturally ventilated houses. The distribution of air was more homogeneous for cross-flow and chimney systems than for tunnel ventilation. As previously mentioned with the natural ventilation system, the location of sidewall openings had a clear effect on air velocity profiles at animals' level.

CONCLUSIONS

A methodology to determine minimum ventilation rate needed in rabbit buildings was developed and tested. For the conditions given, humidity and ammonia concentrations were the most restrictive parameters to determine appropriate ventilation rates. Air velocity patterns and distributions were evaluated for different building types and ventilation systems. The location of sidewall openings had a strong effect on air distribution and velocity. Cross-flow and chimney systems resulted in better air distribution than tunnel ventilation.

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REFERENCES

Calvet S., Cambra-Lopez M., Estelles F., Torres A.G. 2011. Characterisation of the indoor environment and gas emissions in rabbit farms. *World Rabbit Sci., 19, 49-61.*

Cervera C., Fernández Carmona J. 1998. Climatic environment. In: De Blas C., Wiseman J. (Eds). *The Nutrition of the Rabbit. CABI Publishing. CAB International, Wallingford Oxon, UK, 273-295.*

CIGR. 1992. Climatization of animal houses. *Second Report of the Working Group on Climatization of Animal Houses, Centre for Climatization of Animal Houses, Ghent, Belgium, 1-147.*

CIGR. 2002. Climatization of animal houses. Heat and moisture production at animal and house levels. *Pedersen, S. y Sälvik, K. Danish Institute of Agricultural Sciences, Horsens, Denmark, 1-46.*

Estellés F., Rodríguez-Latorre A.R., Calvet S., Villagrá A., Torres A.G. 2010. Daily carbon dioxide emission and activity of rabbits during the fattening period. *Biosyst. Eng. 106, 338-343.*

Frangiadaki E., Golidi E., Menegatos E., Luzi F. 2003. Comparison of does' performances under high and moderate temperature in a Greek commercial farm. *World Rabbit Sci. 11, 137-143.*

Garcimartin M.A., Ovejero I., Sanchez E., Sanchez-Giron V. 2007. Application of the sensible heat balance to determine the temperature tolerance of commercial poultry housing. *World Poultry Sci. J., 63, 575-584.*

Marai I. F.M., Habeeb A. A.M., Gad A.E. 2002. Rabbits productive, reproductive and physiological performance traits as affected by heat stress: a review. *Livest. Prod. Sci., 78, 71-90.*

Ogunjimi L.A. O., Osunade J.A., Alabi F.S. 2007. Effect of ventilation opening levels on thermal comfort status of both animal and husbandman in a naturally ventilated rabbit occupied building. *Int. Agrophys., 21, 261-267.*

Sahuquillo J., Villagrá A., Blanes V., Torres C., Torres A.G. 2004. Effects of ammonia concentration on reproductive performance in rabbits. *In Proc. AgEng 2004, September, Leuven, Belgium, 698-699.*

Villagrá A., Blanes-Vidal V., Torres A.G. 2004. Introducción a la climatización de granjas cunícolas. *Boletín de Cunicultura, 131, 12-18.*