Effect of air flow rate regulation on the performances of evaporative cooling during hot periods

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In order to avoid mortality due to heat stress more and more farmers equip their poultry buildings with evaporative cooling systems. Regulation of the air renewal has direct consequences on temperature, relative humidity and sometimes air speed inside the building. During hot periods, evaporative cooling decreases the temperature and increases the relative humidity inside the building. These changes are complex because animals reduce their latent heat production when the indoor temperature decreases. In this paper, we present simulations made with software developed by INRA and ITAVI (Robin et al, 2005). It is distributed to improve the design and the regulation of evaporative cooling system.

We first assessed a combination of air flow rate and water flow rate ($Qair_{dim}$,$Qwater_{dim}$) which allows one to achieve indoor temperature and relative humidity of (30°C; 70%) as a function of given outdoor temperature and relative humidity (35°C; 30%), animal species and weight (broilers of 1,9kg), livestock building characteristics and stocking density (18 broilers/m^2). We then varied the air flow rate around the value determined previously. A weak diminution of the ventilation rate without changing the evaporated water flow rate improves the cooling effect but it increases the relative humidity (fig. 1). In the final breeding days, if the water rate is limited because of the design of the cooling system, the increase in relative humidity can be tolerated because the quality of the litter is not important. For a lower air flow rate, it becomes impossible to evaporate all the available water and to cool the ambient air. In this case the liquid water can contribute to the deterioration of the litter if cooling is used for a long period.

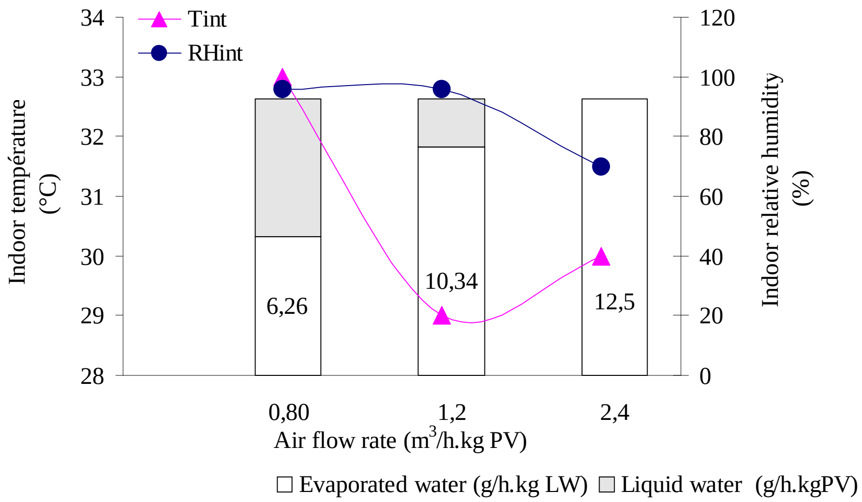

Figure 1 Variations of the indoor temperature and relative humidity for Dair <$Dair_{dim}$ et Dwater=$Dwater_{dim}$

Conversely, if the ventilation increases, the water flow rate required to reach an indoor temperature of 30°C is higher than $Qwater_{dim}$ (fig. 2). We noticed also that the relative humidity inside the building is less than 70%. The required water is more important because a higher ventilation rate involves more hot air coming in and more fresh air going out of the building. In this case, the water and the electricity consumption (if the ventilation system is dynamic) will be increased in comparison with the optimal cooling situation. A smaller indoor relative humidity can be required with high air speeds in order to keep the litter dry. Moreover, the water flow rate may not be enough to keep the optimal cooling effect. Therefore, we recommend the development of technical solutions that will allow simultaneous control of the air and water flow rates, where the farmer will have the opportunity to choose either a low indoor relative humidity to keep the litter dry or a cool indoor temperature to avoid animal mortality at the end of a breeding period. Such a solution is similar to that proposed by Aerts et al (2003).

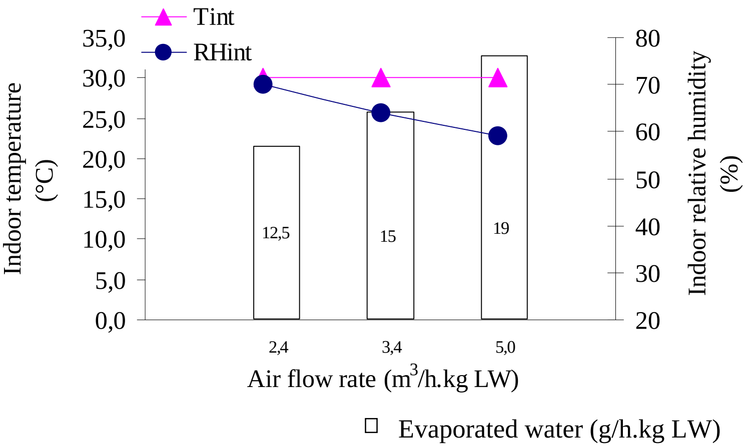

Figure 2 Variations of the indoor temperature and relative humidity for Dair >Dairdim et Dwater ≠ Dwaterdim

The optimal cooling effect (a compromise between temperature decrease, inside relative humidity, water and energy consumption) for given indoor and outdoor temperature and relative humidity, livestock building type, animal species and stocking density corresponds to one combination of air flow rate and water flow rate. Increasing or decreasing the air flow rate breaks this equilibrium and leads to different indoor climatic conditions (higher temperature or relative humidity) and to waste water (all the water is not evaporated or to much water is required). Thus, in order to limit the economic damages due to heat stress, it's necessary to assess the regulation of the ventilation and the cooling prior to the use of the cooling system.

References

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