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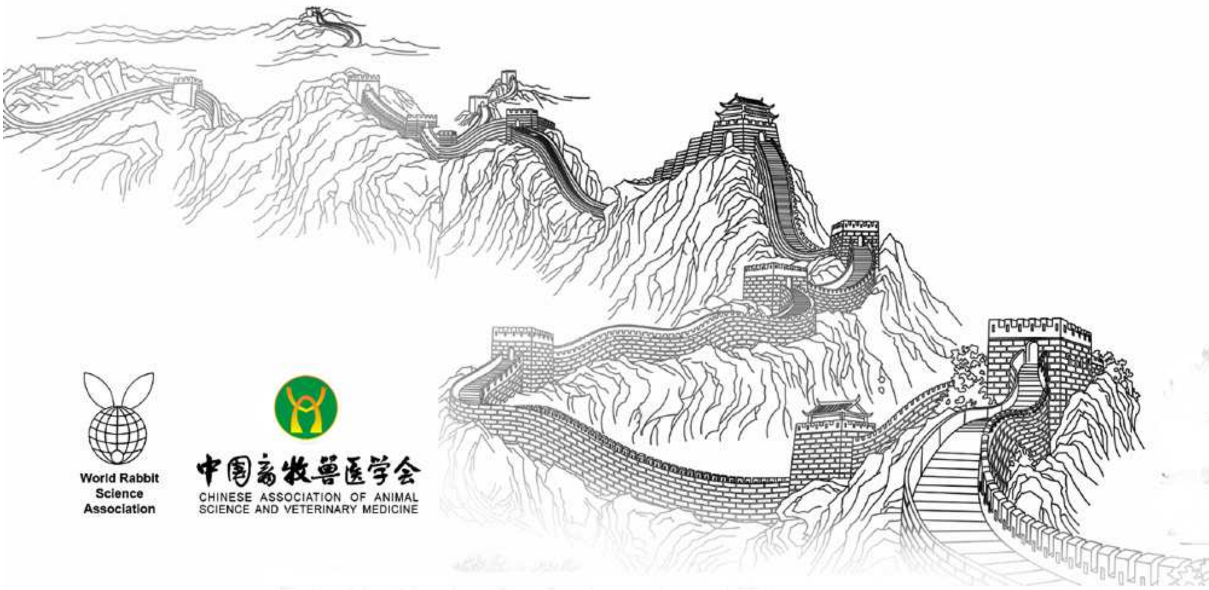

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A MODIFIED HEAT RECOVERY VENTILATION SYSTEM FOR RABBIT HOUSES IN COLD CLIMATES IN NORTH-EAST CHINA

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ABSTRACT

The objective of this study was to determine the feasibility of using a modified heat recovery ventilation system (HRVs) in a rabbit house as a source of fresh air preheating to improve the indoor air quality in cold region. An air-to-air heat recovery ventilation system was tested in a rabbit house in Jilin Province (Northeast China). When compared with the control house, the average temperature of the treatment house had no significantly decline when a minimum ventilation rate was applied (P>0.05). The relative humidity, the concentrations of ammonia and carbon dioxide were lower than those in the control house(P<0.05).The system had a moderate performance on sensible heat recovery effectiveness, and no significant difference was observed when the outdoor temperature varied from -15°C to 5°C. Sensible heat recovery effectiveness could be significantly affected by motor heat generation. The system was proved more able to resist freezing in cold working condition than the traditional one.

Keywords: heat recovery, ventilation, energy conservation, rabbit house

INTRODUCTION

In cold seasons, large amounts of the energy are lost in the form of heat in the air exhausted from animal building ventilation. Even a minimum acceptable ventilation rate may contribute to a sharp indoor air temperature decline (Vassilakis and Lindley 1998).

Compared with residential buildings, animal houses need a higher ventilation rate (ASHRAE Stan9; Seedorf et al., 1998). It contributes a higher level of heat loss. The traditional mechanical ventilation and natural ventilation is not suitable to be used in severe cold climates, for the reason that cold supply air creates drafts and increase in heat loss during ventilation (Clanton et al., 1990).

Heat recovery ventilation (HRV) has a temper impact on indoor air temperature. The system used an air-to–air exchanger to retrieve energy from warm exhaust air to preheat the cold supply air. The cold fresh air gets an amount of heat from the warm exhaust air. The two air streams are isolated preventing any air contamination by the exhausted air.

Operating animal buildings is energy intensive. Therefore, HRV has potential for application in animal houses. In addition, application of HRV in animal house can improve profitability and reduce the carbon footprint for farms seeking improvement of environmental quality.

The objective of this study were to:(1) Design and optimize the HRV to make it more suitable to be construct, install, and operate in a rabbit house; (2) Evaluate the ventilation effectiveness and the heat recovery effectiveness of the HRV in the rabbit house; (3) Assess the anti-frozen capacity of the HRV in cold weather condition; (4) Evaluate the economic feasibility of the HRV for rabbit house ventilation.

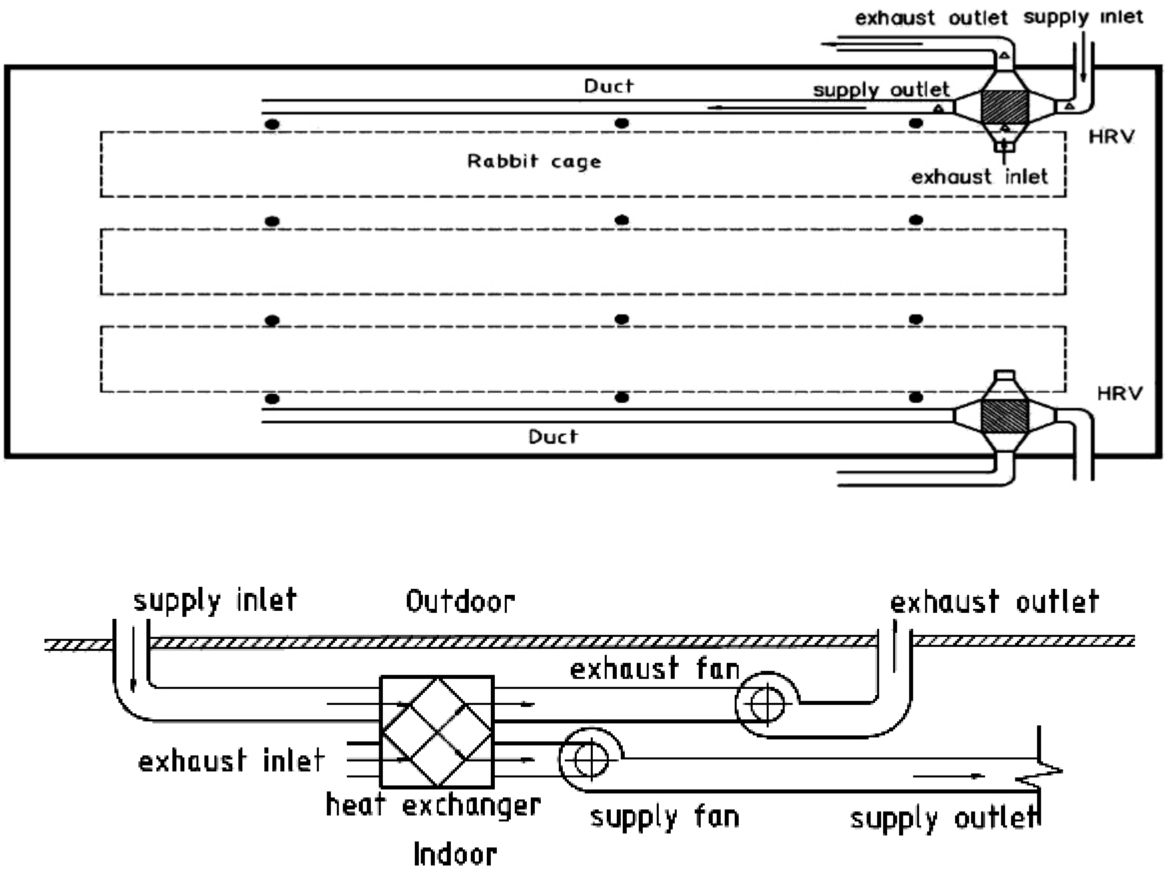
MATERIALS AND METHODS

Equipment and buildings

The experiment was conducted in two rabbit houses in Jilin Province in China. The two experimental rabbit houses were built and instrumented identically. The indoor temperature was maintained by the heat generated by the rabbits in it, and no supplemental heat was provided. The treatment house had two HRVs installed to provide the minimum ventilation, and the control house was ventilated 1hour each day by a tunnel fan (Vane axial).

Description and design of the heat recovery ventilator

The ventilation system consisted of a supply fan, an exhaust fan, an air-to-air heat exchanger and an air duct (Figure 1).



● Indoor air temperature and humidity measure points. ▲ Air flow temperature measure points

Figure 1. The arrangement of the heat recovery ventilation system

The temperature of the flowing air was used to calculate the sensible effectiveness of the heat exchanger. The sensible heat recovery effectiveness of the HRV was calculated using the equation (ASHRAE, 2008):

$$\varepsilon = \frac{C_s(T_{so} - T_{si})}{C_e(T_{ei} - T_{si})}$$

Taking the electrical energy consumption of the fans into account, a parameter was used to deal with it as the coefficient of performance (COP; Roulet et al., 2001), as the following equations show:

$$COP = \frac{Q}{W_e} \qquad Q = C_{1p} M_{1p} (t_{1i} - t_{1e})$$

RESULTS AND DISCUSSION

Improvement of indoor environment

During the operation of the HRV, the average air temperature of the treatment house and control house were 11.61°C±1.62°C and 11.73°C±1.56°C, respectively (P>0.05). The concentration of NH_3 and CO_2 in the treatment house was significantly lower than the control house (P<0.01), with a reduction of 15% and 27%, respectively. Similarly, the RH in the treatment house was significantly lower than the control house, with a difference of 18.9 % (P<0.01; Figure 2). The results reveal that the HRV system can effectively maintain a better indoor air quality without significantly air temperature decline.

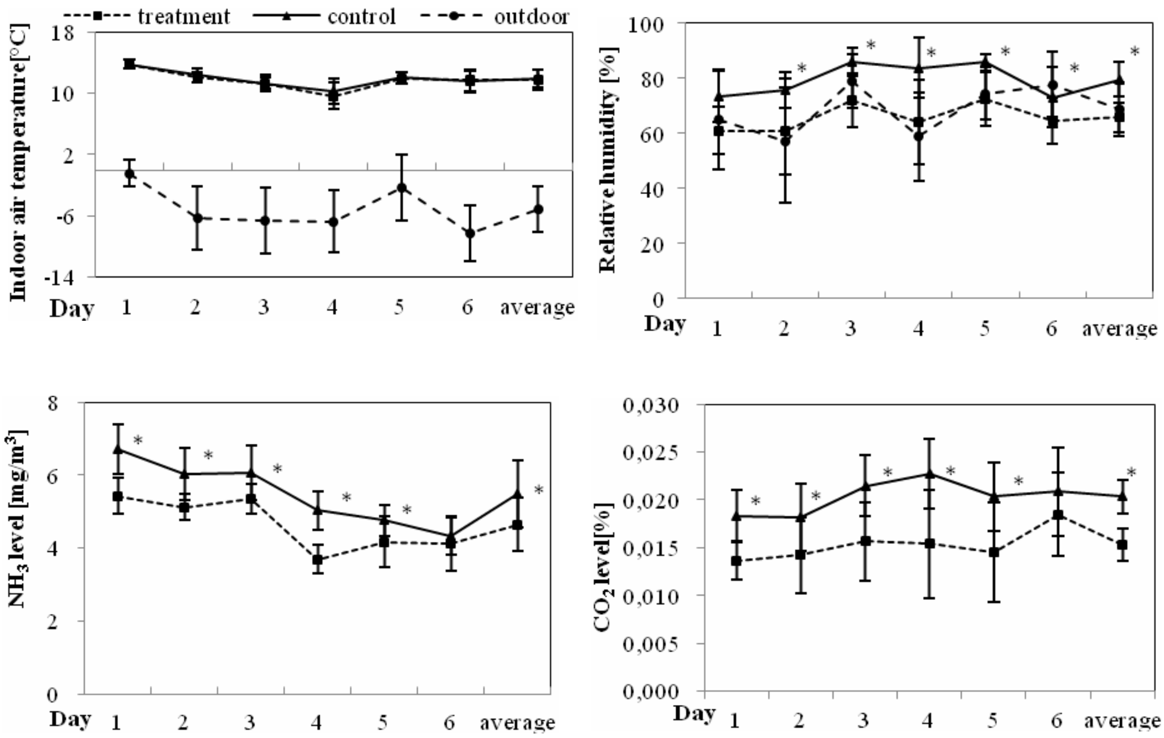


Figure 2. Environment parameters (mean value±SD) of the experimental rabbit houses.
The symbol (*) indicates significantly different values (P< 0.05) between treatment and control house.

Measurement of the HRV performance

The elevation of the supply air temperatures through the heat exchangers was 14.7°C. The sensible heat effectiveness of the unit was 73.0%. Meet the requirement of GB 50189-2005 for the energy efficiency of public building (GB, 2005a). The previous studies in residential buildings show that the general sensible heat effectiveness of HRV are 55%-80% (Mardiana et al., 2012). It is evident that the freezing in the heat exchanger caused by cold inlet supply air has a dramatic effect on the temperature effectiveness of the heat exchanger (Kragh et al., 2005) (Zagorska and Ilsters, 2009). The new HRV used in the experiment was capable of continuously defrosting the ice without using preheats equipment. Ice formation has not become severe until the temperature of the incoming air dropped to approximately -15 °C.

The high sensible heat recovery effectiveness and the less ice formation revealed that the HRV system was well designed and suitable for rabbit houses during the winter in east China.

In this experiment, when air passed through internal fans, the air temperature elevated by 1.8°C due to the heat gained by the internal heat generation of fan motor. This phenomenon suggests that there is approximately 10% increase in sensible effectiveness (Han et al., 2007).

Economical feasibility analysis

A considerable amount of energy can be recovered by the HRV during ventilation. It is reported that HRVs can reduce 14–20% of the fuel heating costs in a commercial poultry barn in the winter (Liang et al., 2011). Our studies showed that the HRV had a good COP performance (16.5–19.2). A COP value of >2.5 indicates that the HRV is efficient (Kang et al., 2010). It was estimated that the ROI (return on investment) of the HRV technology varies from 4 to 5 years (Zagorska and Ilsters, 2009). The improved air quality is beneficial to rabbit health, contributing to less respiratory diseases, which make more profit.

CONCLUSIONS

The new design HRV system had a good performance on ventilation and energy effectiveness. The HRV is recommended for animal house with or without heating system in cold climatic zone. The future work will focus on the influence of duct arrangement on indoor air distribution and the performance of the HRV.

ACKNOWLEDGEMENTS

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