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Rating of an air-to-air tube-type heat exchanger in a piglet house

Due to the high temperature requirements of weaners, especially in the winter months, there is high energy consumption for rearing piglets. Furthermore the economic trend shows increasing energy costs. Thus, it is necessary, inter alia, to evaluate particular technologies to minimize the demand of energy consumption in order to reduce the costs. Air-to-air tube-type heat exchanger offers a convective transmission of heat from waste air to inlet air by using a specific airflow-control-system. Above all the heat energy can be decreased due to the warmed up inlet air which leads to an amplitude attenuation especially in the winter months. The Institute of Agricultural Engineering from the University of Bonn has examined the air-to-air tube-type heat exchanger of the Möller GmbH company for the purpose of acquiring representative data of this regenerative technology.

Keywords
energy efficiency, heat recovery, barn climate

Abstract
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Because their own body heat production is limited, requirement for extraneous heat by housed weaned piglets is relatively high when distributed over the whole year [1]. This deficit of body heat has to be compensated for right up to the thermoneutral zone and requires, especially in winter, an enormous input of heat energy, often only able to be supplied through use of fossil fuels, e.g., gas or oil [2].

On livestock feeding farms the question increasingly asked is how primary energy inputs can be sustainably reduced for production costs savings [3]. In the same way, reduction of CO_2 emissions is being encouraged from all social and political levels [4]. More efficient utilisation of fossil resources and further development of regenerative energy systems must therefore be striven for.

For this reason both farmers and companies building livestock housing seek solutions for the following questions:

- Which technologies enable more efficient utilisation and savings of primary energy?
- How much primary heat energy may be saved in the long-term through application of heat exchangers?
- How efficiently do heat exchangers work in practical farming conditions?
- Which additional advantages do heat exchangers offer for the interior climate in livestock housing?

The in-house temperature requirement for weaned piglets lies at around 26° C [5]. Thus, in winter, when the difference between outside and in-house temperatures is highest, the greatest requirement for heat energy occurs. For maintaining an optimal in-house climate under extraction of noxious gases and water vapour, the aeration within forced-ventilated heated housing must be on the basis of so-called minimised airflow. Hereby, however, there occur unavoidable heat losses. Where there's no technology applied to retrieve this heat, its loss can represent around 80 % of the total heat loss from such housing [6].

The first versions of heat exchangers were hardly ever applied in practice because of their high maintenance requirements and poor efficiency. But current models now include important improvements in materials and design. Major argument for installation of a heat exchanger unit remains the economical advantages offered through saving heat energy. This technology's viability increases in line with the price of the energy that it saves, and the technology also reduces CO_2 emissions.

A preliminary heating of fresh intake air enables air exchange rate (DIN 18910) [5] to be increased without comfort climate conditions being negatively affected. The resultant minimising of noxious gas content in the in-house air can lead to positive effects on animal health and improved working conditions. The University of Bonn Institute of Agricultural Engineering tested the performance potential of a recuperative Möller tube-type heat exchanger in weaner rearing housing at Telgte, Warendorf district. The research was part of a Bachelor degree paper and the results are presented here.

Method and materials

The investigated heat exchanger is installed in a weaner rearing house for a total 2400 piglets. In fortnightly rhythm 300 weaners from 6.0 kg liveweight each are brought in and housed in two compartments.

The air-to-air tube-type heat exchanger is, as shown in **Figure 1**, integrated in the central passage partitioning walls.

Exhaust air is drawn out of each compartment by underfloor extraction. Where there is an increased ventilation requirement in summer, a proportion of the exhaust air can be extracted via additionally installed above-floor vents. In every compartment the warm exhaust air is channelled directly through 40 heat-exchanger tubes in the central exhaust air outlet duct. The PVC tubes have a 145 mm interior diameter, a length of 3100 mm and wall thickness of 2.5 mm. The exhaust air extraction fans are fitted in the front of the building at ridge-height. Fresh intake air enters the exchange system (winter and season transitional periods) firstly via the eaves into the under-rood area. Subsequently the intake air is sucked through the heat exchanger past the exchange tubes and into the central passage of the housing and from there via ventilation slits into the weaner compartments. Multileaf flaps fitted in the gables enable direct fresh air intake and storage in the central passage in summer.

The heat exchanger functions according to the principle of recuperative counter-flow heat exchange whereby a proportion of the heat energy in the exhaust airflow is transferred through a separation layer (the tube walls) by convection to the colder fresh air intake flow. The exhaust air is extracted from the compartments underfloor and channelled through the tubes into the central exhaust air duct. The fresh air from the under-roof area flows in the opposite direction through the heat exchanger system and absorbs a proportion of the exhaust air heat from the tubes.

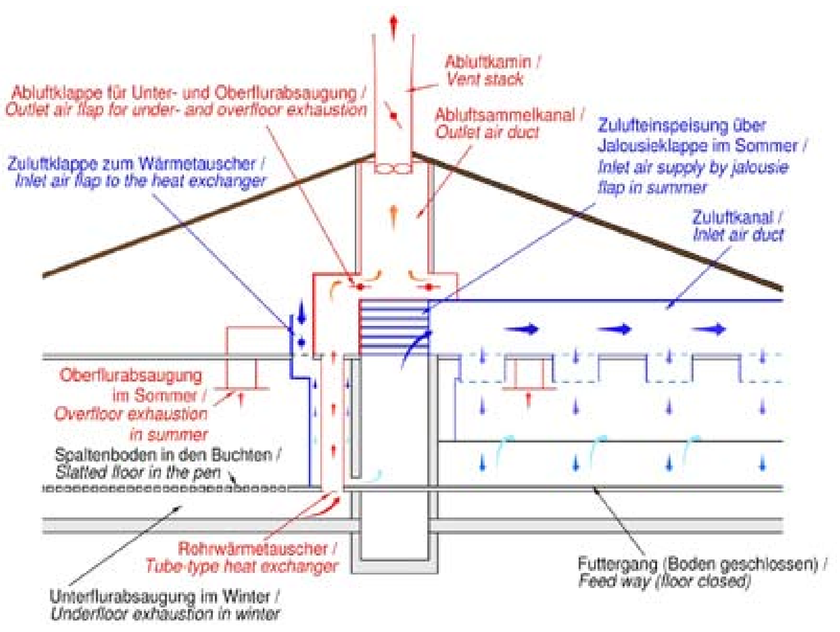
Throughout the test period temperatures and relative air moisture contents of the fresh intake air, the intake air after leaving the heat exchanger, the extracted air pre-heat exchanger and finally the exhaust air post heat exchanger were all recorded every minute by four data loggers (type Almemo 2590 from Ahlborn Mess- und Regelungstechnik GmbH).

Points of measurement were based on VDI guidelines 2071 [7]. Fresh air is taken as the air flowing into the heat exchanger from the under-roof storage area. Intake air is the warmed air after it has flowed through the heat exchanger. The extraction air is that sucked from the weaner compartments before it flows into the heat exchanger and finally the exhaust air is the flow leaving the heat exchanger. According to VDI recording 2640 [8] guidelines, the flow rates of warmed intake air and extraction air were measured with an impeller anemometer. On this basis the percentage airflow rates established by the ventilation computer could be converted into air volume flows [$m^3 \cdot h^{-1}$].

Results

The following results aim to represent a typical winter day (March 3–4, 2010). Temperature progression at the four measurement points is presented in **Figure 2**. The average temperature of the intake fresh air was – 0.8 °C. Through the tube-type heat exchanger, intake air was warmed by 8.2 K to +7.4 °C when it entered the central passage. The extraction air temperature entering the heat exchanger was 29.0 °C and cooled down there by 12.3 K. The exhaust air at leaving the heat exchanger had therefore an average temperature of 16.7 °C. Particularly emphasised in this graph is the effect of the amplitude dampening of the system where temperature progression of fresh intake

Fig. 1



Schematic assembly of the investigated air-to-air tube-type heat exchanger (drawing: Möller GmbH, Diepholz) air before and immediately after the heat exchanger are compared.

Figure 3 shows the heating performance of the air-to-air tube-type heat exchanger calculated on recorded air volume flows. On average, during the recording periods the heat exchanger achieved a heating performance of 21.5 kW, fluctuations due to temperature and mass flow of fresh air intake was between 12.2 and 37.1 kW. As expected, the highest heating performances were achieved with the lowest fresh air temperatures.

Temperature efficiency -ηt describes the relationship of intake air heating to total temperature difference between fresh intake air (entering the heat exchanger) and extraction air (also entering the heat exchanger). With an average temperature difference between these two air flows of 29.1 K, the achieved temperature efficiency of the system would be ηt = 0.27. Increasing fresh intake air temperatures where extraction air temperatures are relatively constant result in sinking temperature efficiency. Within the investigation period the temperature efficiency fluctuated between 0.19 and 0.41 (**Figure 4**).

Conclusions

Heat recovery from the extraction air from forced ventilated heated housing represents a possibility of returning a proportion of the heat which is inevitably transported out with the exhaust ventilation air. Reducing this transported heat thus sustainably decreases required input of primary energy for heating animal housing. Along with associated savings in energy costs this also reduces CO_2 emissions. Required for high air-to-air tube-type heat exchanger efficiency are large ΔT between fresh and extraction air. The air conditioning through the heat exchanger causes amplitude dampening and, with that, a much more uniform temperature of housing intake air. Together with a possible increasing of the air rate, this has a positive effect on animal health. Seen as disadvantages of the heat exchangers applied in this trial were the increased airflow resistances experienced and also the design-influenced reduction in available net floor area within the compartments.

Literature

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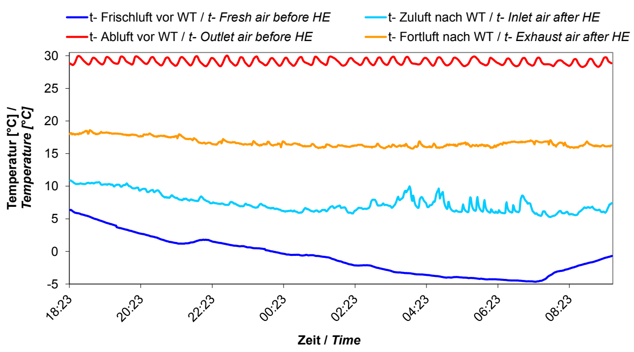
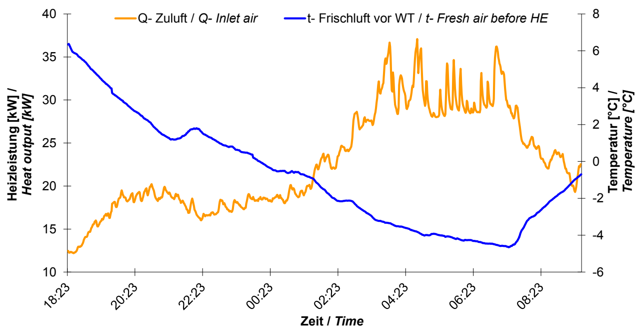
Fig. 2



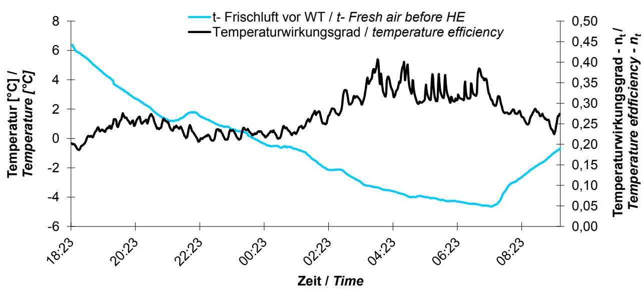
Temperature development at the four measuring points from march 3^{rd}–4^{th}, 2010

Fig. 3



Heat output subjected to fresh air temperature from march 3^{rd}–4^{th}, 2010

Fig. 4



Temperaure efficieny subjected to fresh air temperature from march 3^{rd}–4^{th}, 2010

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