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Rating of an air-to-air heat exchanger in practice

Barn ventilation is often associated with heat loss. This can be regulated by using appropriate heating technology during the cold season. Air-to-air heat exchanger can be used to recover some of the heat from outlet air. Thereby the system transfers some of the heat from the outlet air to incoming fresh air by heat exchange surfaces. For objective review the DLG has multiple tested this technology on test bed. Long term investigations in practice have taken place rarely. The Institute of Agricultural Engineering, University of Bonn, therefore has tested an recuperative heat exchanger in long term study which was installed in a piglet house.

Keywords
Heat recovery, energy efficiency, barn climate

Abstract
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With the background of global climate warming, continuously shrinking fossil fuel reserves, greater dependence on energy imports and strongly fluctuating, but tendencially rising, energy prices the following questions are currently being intensively discussed in agricultural livestock production:

- How might heating costs in livestock production be effectively reduced?
- How can fossil fuels be exploited more efficiently?
- What contribution to energy saving can heat recovery offer?
- What degree of efficiency can be expected from air-to-air heat exchangers in continual use under practical conditions?

In forced ventilated heated livestock housing between 70–90 % of heat loss in winter takes place through the ventilation [1]. As early as the 1980s air-to-air heat exchangers were installed in pig housing to minimise such losses. In practice, however, these failed to become established because their design meant they required a high maintenance input. They were also financially inefficient (high investment costs, low primary energy prices)[2]. Increasing energy prices as well as improvements in technological development regarding air-to-air heat exchangers have in recent times made heat recovery from exhaust air in livestock housing interesting once again. The farmer's decision to purchase an air-to-air heat exchanger is hereby first of all intrinsically linked with the estimated advantage of this investment compared with alternative technology. In turn, this depends substantially on energy price development [3].

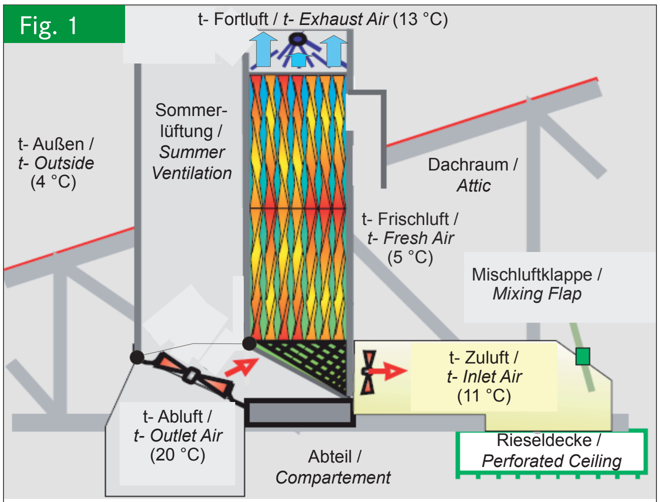
A positive, not entirely monetary, effect of heat recovery is the fuel saving aspect and associated reduction in CO_2 emissions. As far as livestock is concerned the application of an air-to-air heat exchanger is advantageous because through the associated warming of the fresh intake air the minimum airflow rate required according to [4] is often increased and, with that, the air quality in livestock housing improved.

Purely objective evaluations of air-to-air heat exchangers based on physical performance parameters have already been carried out on numerous occasions by the DLG through test stand trials [5; 6]. A big advantage of such standardised investigation methods is the reproducibility and comparability of the resultant measurements because, e. g., on the test stand the parameters air temperature, relative air moisture content, or also air volume flow, can be precisely adjusted and kept constant.

Research-supported statements over performance capacities of air-to-air heat exchangers on farms cannot, however, be based on test stand measurements alone because under practical conditions there are numerous disruptive factors, such as dirt on the exchange surfaces, with direct effects on the technology's energy performance potential. Representing an additional factor influencing heat exchange can be, e. g., the retention time of the exhaust and intake air in the heat exchanger or also the cleaning intervals of the heat exchanger.

The Institute of Agricultural Engineering at the University of Bonn has conducted intensive investigations with a WVTL 480 Schönhammer recuperative heat exchanger in a piglet-rearing barn in Gunzenhausen, Ansbach district, with regard to its energy performance potential. Presented here are the first results from this investigation.

Fig. 1



Schematic assembly of the investigated air-to-air heat exchanger

Materials and method

The tested heat exchanger (**figure 1**) is fitted near the front in the roof space of a 2 000-place piglet-rearing barn, the piglets being housed in nine compartments directly post-weaning, remaining until they reach 30 kg liveweight.

Exhaust air is channelled through a central underfloor suction system. This collects under the central passage the warm exhaust air from the piglet compartments and, during winter, channels it over the heat exchanger and out of the barn. During summer ventilation, directional flaps help channel the exhaust air past the heat exchanger and directly out of the barn. Fresh intake air is drawn into the roof space via eave inlets. From there it is channelled over the heat exchanger with subsequent introduction into the rearing compartments through perforated ceilings.

The tested air-to-air heat exchanger is a recuperative counter-current model. The recuperative models transfer heat convectively from the warmer air current through a separation layer to the colder air current. With the WVTL 480 the fresh air is channelled on the one side from above and through the heat exchanger through smooth, spiral exchange surfaces made of plastic. The warm exhaust air is channelled in the opposite direction, i.e. upwards, from the central exhaust air collection canal. The cooled outgoing exhaust air then leaves the barn. The spiral surface within the heat exchanger increases exchange or contact area between intake and exhaust air. Additionally, the air turbulence thus caused is aimed at increasing the heat conduction. If required the exchange area can be cleaned of dust from the barn through a cleaning system permanently fitted on the exhaust air side.
During the investigation the following measurements were recorded every ten minutes:

- Airflow volume of intake and outgoing exhaust air
- Relative air moisture content and temperatures of the fresh, intake, exhaust and outgoing exhaust air
- Exterior temperature

Results

The period October 2009 to April 2010 was selected for the long-term investigation. The results below are from the study period chosen within this time: March 12–18, 2010. The measured temperature progress at the five measurement points is presented in **figure 2**.

The average exterior temperature was 4.1 °C. Through induction of fresh air from the roof space its temperature could already be increased by 1.5 K. The intake air entering the piglet rearing barn achieved an average temperature of 11.0 °C after passing through the heat exchanger and, with that, lay 6.9 K higher than the outdoor temperature. The exhaust air temperature before entering the heat exchanger was at 19.8 °C and was cooled down to 13.0 °C in the heat exchanger. On the intake air side the fresh air temperature could be increased by an average 5.4 K after passing through the heat exchanger. On the exhaust air side a 6.8 K cooling of the air took place.

Through the fan installed in the air intake, the air volume flow of the intake and outgoing exhaust air during the investigation could be held almost constant. This represented on average 11 465 $m^3 \cdot h^{-1}$ or 11 488 $m^3 \cdot h^{-1}$. Cleaning of the exhaust air side of the exchanger surface need not be carried out in the winter months because condensate production is sufficient to keep the surface clean during this period.
Figure 3 shows the calculated heating performance of the air-to-air heat exchanger on the basis of the recorded air volume flow. On average the heat exchanger during this investigation achieved a heating performance of 21.6 kW. From this there resulted a heat recovery of 3 100 kWh. This represents a heating oil equivalent of around 310 l and an avoidance of 820 kg CO_2 emissions. The energy consumption of the air-to-air heat exchanger is not included in this calculation.

The temperature efficiency-η_t describes the relationship of the intake air heating to total temperature difference between fresh and exhaust air. It can be determined thus:

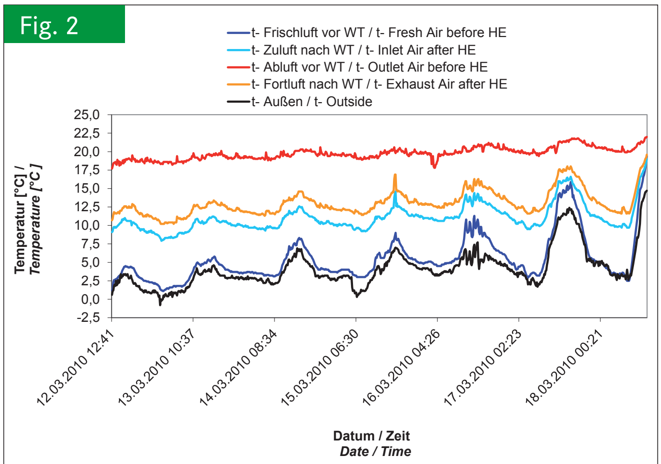
$$\text{Temperature efficiency-}\eta_t = \frac{t_{22} - t_{21}}{t_{11} - t_{21}}$$

with: t_{22}= t-intake; t_{21}= t-fresh air; t_{11}= t-exhaust
The progression of η_t is shown in **figure 4**. With a temperature difference between fresh and exhaust air averaging 14.2 K a temperature efficiency of η_t= 0,39 is achieved. Increasing fresh air temperatures correspond with decreasing η_t. The reason for this is the decreasing ΔT by stable exhaust air temperature.

Conclusions

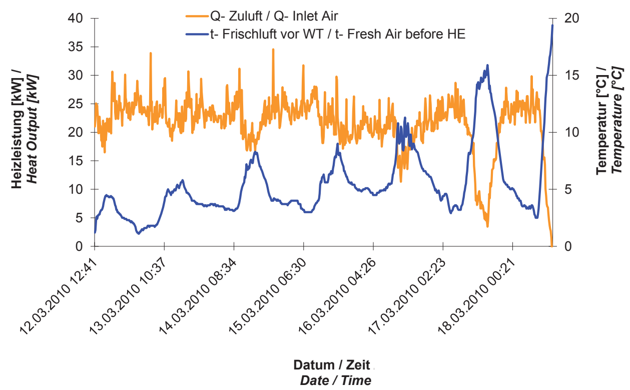
Heat recovery from the exhaust air of forced ventilated heated livestock barns offers the farmer the possibility of cutting heating costs whilst protecting fossil fuel reserves. Only through long-term investigations under practical conditions can the performance potential of this technology be sufficiently quantified. Required for achieving high efficiency with air-to-air heat exchangers are large ΔT between fresh and exhaust air. Through

Fig. 2



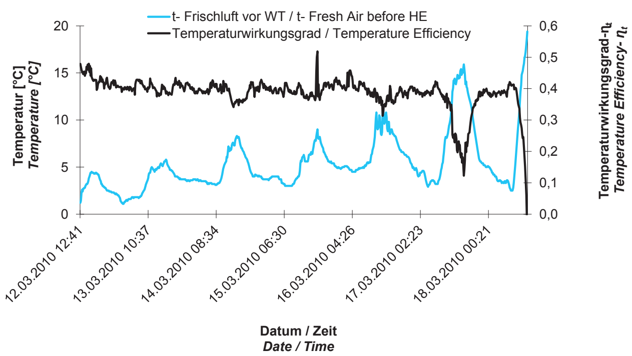
Temperature development at the five measuring points

Fig. 3



Heat output subjected to fresh air temperature

Fig. 4



Temperature efficiency subjected to fresh air temperature

pre-warming of intake air the winter ventilation flow rate can be increased and with that the barn climate sustainably improved. In this way large amounts of primary energy can be substituted.

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