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Earth-tube heat exchanger for all-season conditioning of a farrowing house

With the aid of earth-tube heat exchanger geothermal energy can be used. Geothermal energy is characterised by clearly lower variations in temperature compared to the incoming air. Therefore the earth-tube heat exchanger becomes more popular, on one hand because of energy saving, and on the other hand because of the cooling of the incoming air. Especially in farrowing houses a balanced climate has to be provided throughout the whole year for sows and piglets. By means of earth-tube heat exchanger the incoming air was efficiently cooled or heated resulting in a clear reduction of seasonal and diurnal variation. Earth-tube heat exchangers are a cost-efficient supplement for sustainable air conditioning of farrowing houses.

Keywords
Earth-tube heat exchanger, heat stress, farrowing house, air conditioning

Abstract
Landtechnik 66 (2011), no. 3, pp. 183–186, 2 figures, 1 table, 9 references

In recent years heat production by means of earth-tube heat exchanger (EWT) has gained in importance in building construction in Europe. End of the seventies the great increase of oil prices led to a rethinking concerning energy use. In 1981 the first stable for fattening pigs equipped with an EWT had been put into operation [1].

In the course of further shortage of fossil resources and high oil prices sustainability of livestock houses gets more important than ever. In addition increasing animal performances due to advanced breeding as well as improved housing and management, leads to higher demands for an optimal stable climate particularly with regard to prevent heat stress in summer times.

Especially in farrowing houses a balanced climate throughout the whole year for sows as well as for piglets has to be provided. The different demands to the ambient air temperature for sows and piglets are well-known: Piglets, especially in the first two weeks p.p. need ambient air temperature of about 33 °C. Room temperature of 27 °C and additional heat sources in terms of piglet nest and heat lamp are necessary. However the optimal ambient air temperature for lactating sows is in the range of 10–16°C [2]. Temperatures above the thermo neural range leads the negative effects on feed intake, milk production [3] as well as sow condition including fertility [4–6]. By conditioning income air using EWT heat stress can be reduced.

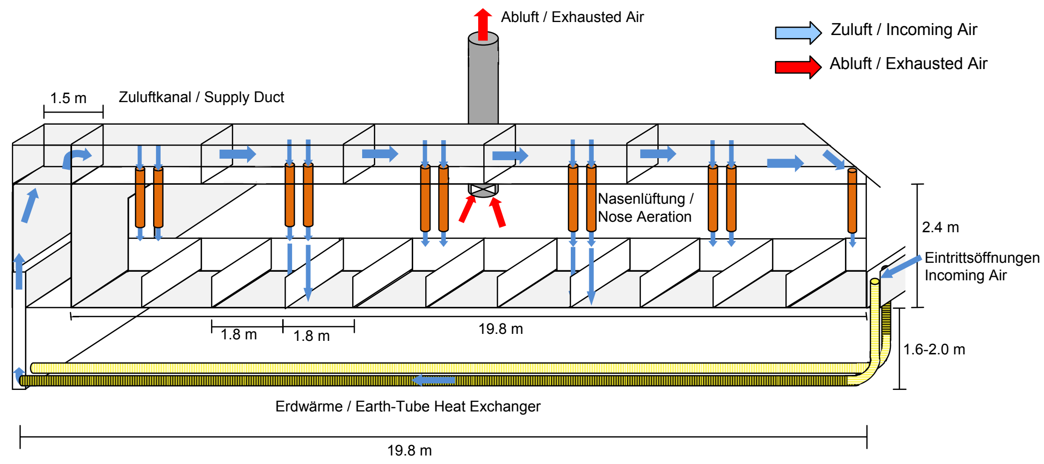
Material und Methode

The study has been carried out in a farrowing house in Northwestern Germany (administrative district of Osnabrueck) which included four compartments with 22 farrowing pens each. The experimental period lasted 12 month.

The farrowing house was built on podsol soil, which featured a groundwater level at a depth of 1 m below ground surface. Underneath the foundation of the farrowing house non perforated ribbed tubes (diameter: 20 cm) were piped in a depth of 1.6–2.0 m. Due to the high ground water level the excavations were filled without washing in of the tubes. Into each excavation 9–8 tubes were piped directly next to each other. The distance between each excavation amounted 0.5 m. In total 88 tubes were piped, which corresponds with the number of farrowing pens in the farrowing house.

The inlet ports of the EWT were directly next to the outer wall. The outlet ports opened out into an air supply duct. From there, the delivery air reached the attic via 5 ducts (1.0 m x 1.0 m). From these attic ducts 88 tubes (diameter 0.2 m) were piped into the farrowing house, one for each farrowing pen. The tubes ended 2 m above the sow's head. This kind of air supply is called "nose aeration". The outgoing air of the compartments was exhausted via one exhaust air duct each using a Multifan pipe installation fan. Exhausted air rate was controlled via airflow and inside air temperature using a climate computer (FC

Fig. 1



Routeing of air flow passing the EWT in the farrowing compartment

12 Fancom, NL). Additionally a frequency converter (Frelink-4f, Vostermans Ventilation B.V., NL) for speed control of the fan was interconnected (**figure 1**).

In the 4th day p.p. infrared lamps (80 W) were hanged up above the nests. Furthermore the warm water heating of the piglets' nest and the sensible heat production of the animals themselves were the only additional heat sources in the stable.

In order to quantify the performance of the EWT air temperature data were recorded at hourly intervals at three measuring points.

Outside air temperature was measured with a WS 2000 PC radio meteorological station (ELV-Elektronik AG, Germany) 20 m away from the farrowing house. At four measuring points air temperature in the masoned air supply duct were recorded hourly with the aid of Micromec Loggers (Datenlogger + Messtechnik GmbH, Germany) and measuring sensors (Rotronic Messgeraete GmbH, Germany). Air temperature in compartment 1 & 3 were registered in the middle of the compartment at a height of 1.80 m using Tinytag Datalogger (Gemini Data Loggers Ltd., Great Britain).

Because of malfunction of the measuring technique no data are available for outside climate from September 2nd to October 2nd 2009 and for the supply duct climate from 8th October to 4th November 2009.

Results

On basis of hourly means average outside air temperature was only by 2.4 °C lower compared to the supply duct air temperature after passing the EWT (**table 1**). However standard deviation of outside air temperature was clearly higher compared to the one of supply duct air temperature. The range for outside air temperature represented 49.1 K. Highest measured outside air temperature was 35.1 °C, lowest outside air temperature -14.0 °C. After passing the EWT temperature variations could be clearly reduced. The range between the maximum of 21.5 °C and the minimum of 6.5 °C resulted in 15 K. During winter time incoming air (supply duct) was heated by up to 20 K compared to outside temperatures. In summer time incoming air was cooled by up to 14 K. Reference base are the hourly means.

Overall Air temperature variation of incoming air temperature can be minimized by 70 % by means of air conditioning using an EWT.

On basis of daily means incoming air could be cooled after passing the EWT by up to 6 K. In winter times a warming of incoming air by up to 14 K could be reached. These air temperature differences correspond with findings of Huijben et al. [7]. These authors analysed the cooling, heating respectively of air after passing an EWT, which was built underneath an fattining house. They reported air temperature differences in summer

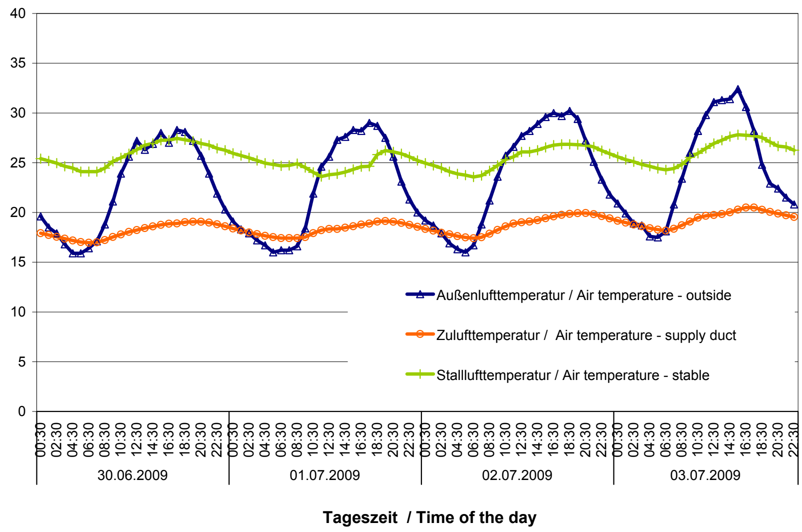
Table 1

Mean, standard deviation (SD), maximum, minimum as well as range of the air temperature outside and in the supply duct (n = 7223 hourly means)[1)]

	Mittelwert *Mean*	SD	Maximum	Minimum	Spannweite *Range*
Außenlufttemperatur *Outside air temperature [°C]*	10,0	8,3	35,1	-14,0	49,1
Lufttemperatur im Zuluftkanal *Supply duct air temperature [°C]*	12,4	3,8	21,5	6,5	15,0

[1)] *Data from September 2nd – October 2nd 2009 and from 8th October – 4th November 2009 are not included.*

Fig. 2



Air temperature from outside and supply duct and stable air temperature on hourly basis for 4 consecutive example days during summer time (n = 96)

times of 4–8 K and in winter times of 4–10 K compared to outside temperatures.

Higher air temperature differences in winter times could be due to the lower air flows.

Lower air flows lead to higher temperature differences [8], because the air flow within the exchanger tubes influences the temperature difference between outside air temperature and air temperature after passing the EWT.

Besides the heating and cooling of the air, the damping of the temperature fluctuation is a further advantage of the EWTs, which becomes effective in summer times as well as in winter times. Day-night variations of outside air temperature were found in this one year lasting study to be up to 19.8 K, by air condition via EWT these diurnal variations were clearly reduced with maximal variations of only 3.8 K

Using the example of four consecutive summer days in year 2009 (**figure 2**) the air temperature variations of outside air, conditioned air as well as stable air are shown.

In these days maximal outside air temperature variation amounted 14.2 K. After passing the exchanger tubes the diurnal variations of the incoming air were only 2.5 K and correspond with finding of [9]. These authors reports maximal air temperature variations after passing the EWT of 3–4 K.

Conclusions

With the aid of an EWT in a farrowing house incoming air could be efficiently cooled (summer), heated (winter), respectively, whereby seasonal as well as diurnal air temperature variation could be clearly reduced. EWT's are cost effective supplement for sustainable air conditioning of farrowing houses.

With new constructions an EWT is undoubtedly associated with higher capital investments. However the installation of an EWT becomes profitable due to energy savings and better animal health. In summer times the probability of heat stress of sows are reduced. Furthermore required ventilation rates can be minimized, which leads to energy savings. In winter times heat costs can be reduced.

For evaluation of the amount of saved energy in subsequent studies further sensors are installed. Continuous online ventilation rate will be recorded using a measuring ventilator, furthermore pressure difference measurement will be done with online sensors, and the electric energy consumption of farrowing house as well as heat energy consumption of hot water floor heating system will be registered.

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