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Comparison of different air supply and cooling systems in pig fattening houses

There is a need for research regarding the optimization of air supply and of air cooling systems of livestock houses for fatteners. A decision support project for the German Ministry of Agriculture has been established to investigate such technologies on a research farm and under practical conditions. Since April 2011, on the research farm Landesanstalt für Schweinezucht (LSZ Boxberg) measurements on three air supply and cooling system are carried out: Underfloor air inlet and supply, cooling pad and high pressure evaporative indoor air cooling. First results show differences concerning the parameters temperature, differential pressure and air velocity.

Keywords
cooling systems, cooling pad, underfloor air inlet, high pressure humidifier

Abstract
Landtechnik 66 (2011), no. 5, pp. 349–353, 4 figures, 1 table 1 reference

The laws governing animal welfare (TierSchNutztV 2009) set out under § 22 that facilities must be present in pig houses to limit the exposure of pigs to thermal stress during periods of high air temperatures within the house. Research into the design and management of the cooling facilities and/or preconditions and performance benchmarks is needed, especially since a funded database for assessing the efficiency of cooling facilities and consumption of resources as well as the effect on the climate of the house and the environment does not exist. For this reason, several air supply and cooling systems are being tested at the Landesanstalt für Schweinezucht (LSZ) in Boxberg and at three other research farms as part of an extensive, two year study to aid the BMELV in reaching a decision. This report focuses on the initial, exemplary results relating to temperature, air speed and negative pressure measurements taken during ongoing comparison tests at LSZ Boxberg, which began back at the start of 2011.

Materials and methodology

The experiments at LSZ Boxberg are being carried out in pig fattening houses, which are themselves divided into four, structurally-similar compartments, each with six pens. The pens are equipped with fully slatted floors and sensor-controlled, liquid feeding. One compartment holds 125 animals per fattening period. One pen contains between 20 and 22 animals and provides an area of 1.10 m^2 per animal. The animals entered the house with a weight of 28 kg, which had increased to 118 kg upon removal from the house after 17 weeks. **Table 1** summarises the various air supply and cooling systems in the four, experimental compartments.

The study focuses on the parameters of temperature, humidity, differential pressure, air speed and airflow rate. Additionally, energy and water consumption are also measured as well as the concentrations and emissions of gases such as ammonia, carbon dioxide and methane. After all, aspects of both animal welfare and cost-effectiveness should be included in the overall assessment. The stated parameters, which determine the climate of the house, are recorded using Ahlborn data acquisition products at intervals no greater than one minute. Data relating to electricity and water consumption are recorded using data acquisition products, specifically meter readers, from Wago. Concentrations of noxious gases are recorded on a quasi-constant basis using 1412 multi-gas monitors from LumaSense. These data acquisition systems are linked to a central database, in which all raw data is entered and stored.

Measuring sensors were installed in the following four areas to measure the climate in the house: a) Outside area; b) Path from outside to animal area and/or air supply; c) Animal area; d) Path out of the animal house (exhaust air). **Figure 1** illustrates the positions of the sensors along the air paths as well as the change in temperature at low outside temperatures during the course of underfloor air inlet tests.

Outside temperature measurements are subject to the location of the air supply entry point which depends on the method

Table 1

Air supply and air cooling variants at the research farm

	Referenz ***Reference***	**Unterflurzuluft** ***Underfloor air inlet***	**Hochdruckbefeuchtung** ***High pressure evaporative***	**Kühlpad** ***Cooling pad***
Zuluft *Air supply*	von außen über Dachraum und Porendecke *from outside through the attic and porous ceiling*	von außen über zentralen Unterflurkanal mit Unterflur-Eintritt in Versorgungsgang des Abteiles und Überströmung der Buchtenabtrennungen *from outside through the underfloor canal to the compartement*	von außen über Dachraum und Porendecke *from outside through the attic and porous ceiling*	an Stirnseite des Stallgebäudes über Kühlpad (Flächenkühler auf Wasserbasis), dann über Dachraum und Porendecke *from frontside of the pig houses through the cooling pad via attic and porous ceiling*
Abluft *Exhaust air*	dezentral Messventilator *local measuring fan*	dezentral Messventilator *local measuring fan*	dezentral Messventilator *local measuring fan*	dezentral Messventilator *local measuring fan*
Kühlung *Cooling*	ohne *without*	Wärmetausch an Unterflurkanalwänden *heat exchange at the walls of the underfloor canal*	Hochdruckbefeuchtung der Stallluft (ggf. auch zur Befeuchtung im Winter) *high pressure evaporative indoor air cooling (also to use in the winter)*	Befeuchtung der Zuluft (nur bei Außentemperatur > 24 °C) *humidifying the inlet air (only at outside temperature > 24 °C)*
Heizung *Heater*	Deltarohre unter der Porendecke *delta tubes below porous ceiling*	Wärmetausch an Unterflurkanalwänden *heat exchange at the walls of the underfloor canal*	Deltarohre unter der Porendecke *delta tubes below porous ceiling*	Deltarohre unter der Porendecke *delta tubes below porous ceiling*

of air supply used. Therefore measurements are taken close to floor level when the underfloor method is used and at a height of 3.20 m in the other three compartments, which feature air supply entry points in the attic. Temperature, humidity and air speed sensors are installed at a height of 80 cm in the animal area inside the pens. Further humidity and temperature sensors are located in the exhaust air together with a measuring fan. Trough water consumption is recorded as a cumulative value. Additionally, water meters have been installed along supply lines to the high pressure humidifier system and the cooling pads. Heat meters are also located on the heating supply lines to the compartments and the Wastra panels (used to protect against frost in the entry area of the underfloor air supply duct). Door contact terminals ensure that measuring intervals, in which the door has been left open for prolonged periods, are automatically excluded from data analysis.

Initial results

This report focuses on the initial results of temperature and negative pressure measurements taken during the comparison tests, which have been ongoing since the beginning of 2011 at LSZ Boxberg. Two days, each representing ideal winter and summer conditions, are discussed here as well as data taken from differential pressure comparison measurements.

The winter day

The average temperature on 31.01.2011 for measurements taken at a height of 3.20 m was around -7 °C, whilst the temperature measured at the floor level entry point for the underfloor air supply method was 1.6 K higher. The air supply temperature varied depending on whether above-floor or underfloor air supply was used **(Figure 2)**. A slight warming of the air was measured in those instances where the air supply passed through the attic. When compared with exterior air temperature measured at 3.20 m, the temperature below the first third of the attic was on average 2.5 K higher and 0.8 K higher up to the second third of the attic.

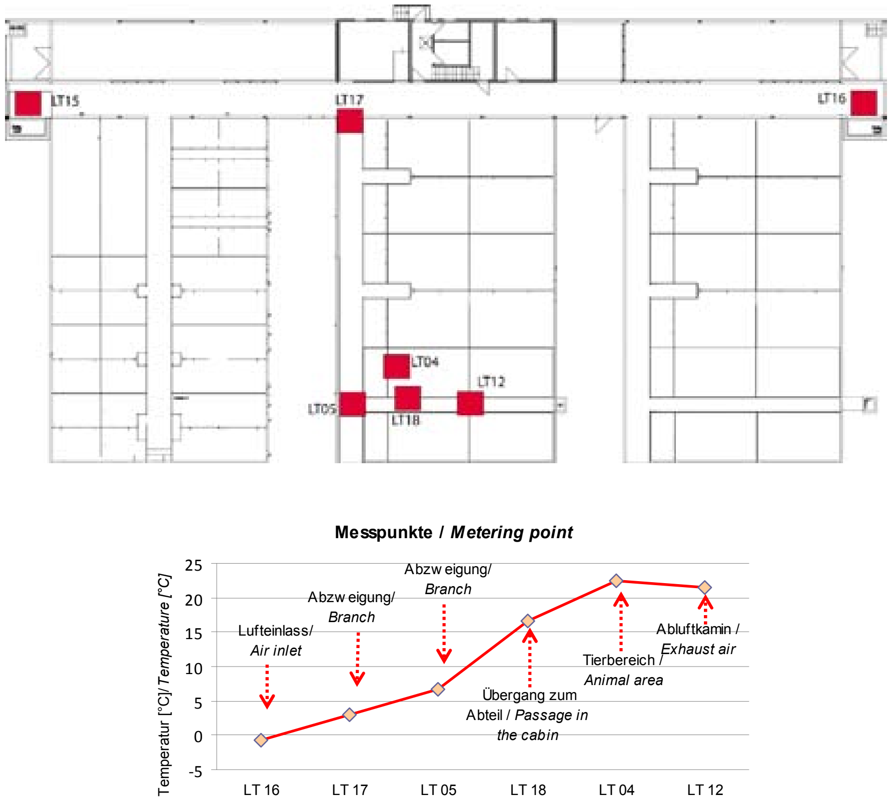
The warming effects recorded with underfloor air supply were significantly greater as can be clearly seen in **Figure 2** with temperature differences ranging between 7 K and 13 K between the exterior sensor (floor) and along the underfloor duct (1st and 2nd branches). The underfloor ducts are divided into two areas. A heater for frost protection is located in the front area before the first branch point **(see Figure 1)**. This has an additional effect on the amount of heat recorded. In the rear part and sections of the duct there are no other heat sources. In the first area, which is 32 m in length, the air is warmed on average by 7 K. The Wastra panels gave off 189 KW/h of the entire day. In the second part of the air duct (26 m long), the temperature was raised by a further 3 K.

Aside from temperature, other climatic parameters such as differential pressure and air speed were measured. These parameters did not vary significantly with respect to the different air supply methods used during winter conditions. The underfloor method demonstrated the lowest air speeds in the animal area.

Summer day

A stable temperature reading within the tolerance range of the set temperature is also desirable in summer. However, this poses a greater challenge for the air supply system as greater fluctuations between day and night temperatures exist. On 27th June,

Fig. 1



Position of the temperature sensors and course of temperature at a cold day using the example of the variant underfloor air inlet

2011, the daily low measured 14 °C whilst the daily high measured 30 °C. This represents a temperature difference of 16 K with respect to the outside temperature measured at a height of 3.20 m before the air is allowed to enter the attic. **Figure 3** shows the range of temperatures recorded in the animal area for the various air supply or cooling systems with respect to the outside temperature. The temperature in the control (reference) compartment demonstrates the greatest range and the temperature in the animal area is, at some points, higher than the outside temperature. The relevant target values for temperature (between 18 °C and 22 °C), which are based on animal weight, were exceeded in all compartments. However, the maximum compartment temperatures for the various cooling methods do not exceed the maximum outside temperature and the range of temperatures over the day remain subdued.

Measuring differential pressure

Differential pressure measurements in the compartments offer an indication of the air current resistance located along the path to the compartment. It has been shown that a difference exists between underfloor and overfloor air supply via the attic and porous ceiling when the airflow rate is at its maximum. A four hour period was selected during which the airflow rate was operated at 100 % capacity to allow a suitable comparison. All the various air supply systems were set to summer operating conditions (maximum air inlet size).

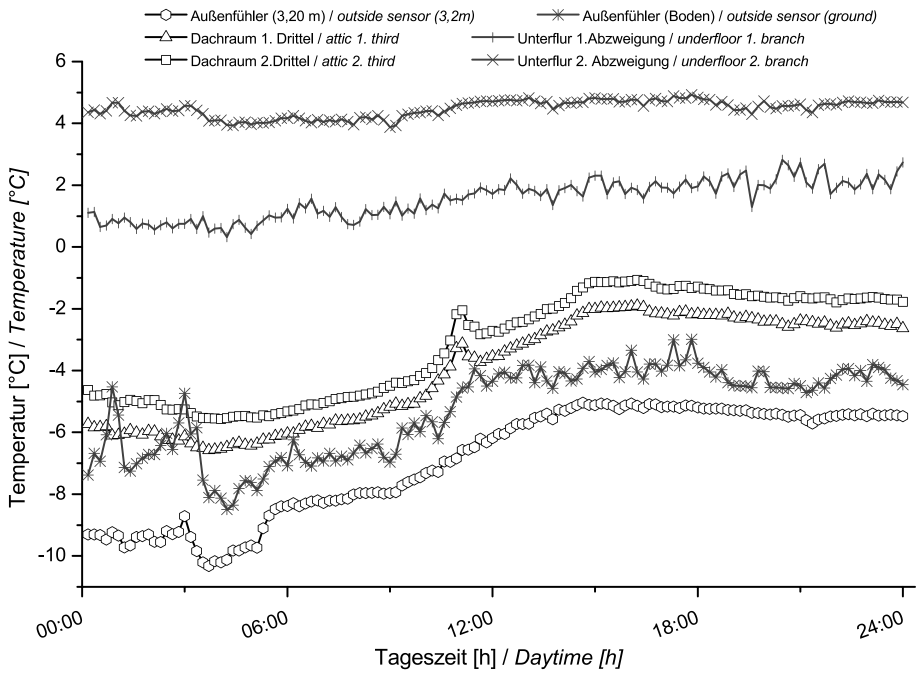
As **Figure 4** shows, the majority of values for overfloor air supply lay between -11 Pa and -15 Pa, whilst values for the other two compartments with overfloor air supply were less than -25 Pa (except for a few isolated values). Opening of the compartment door was determined as the cause of the anomalous, negative pressure values for the control compartment and the high pressure humidifier compartment.

The porous ceiling with its fleece covering represented a significant cause of air resistance at high airflow rates. The air pressure was found to be lower in the high pressure humidifier compartment as this compartment is located before the control (reference) compartment meaning that the path which the air travelled is shorter. In the compartments using the cooling pad system, the air is first redirected in the attic and then guided through the porous ceiling with fleece covering.

The electricity consumption of the fan is proportional to the negative pressure. This means that so long as the quantity of transported air remains constant, electricity consumption of the fan is greater in those systems with a greater amount of negative pressure.

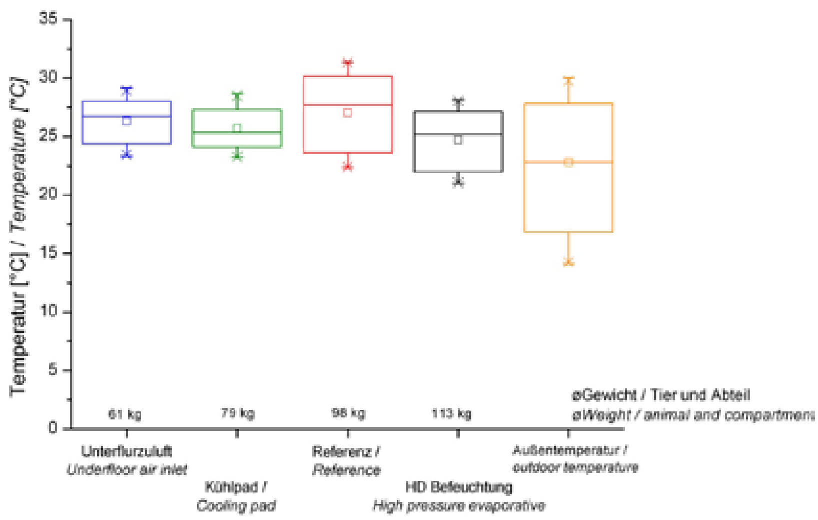
For the time interval shown in **Figure 4**, the quantity of transported air remained practically constant. This means that

Fig. 2



Difference in temperature rise between air supply via attic or underfloor

Fig. 3



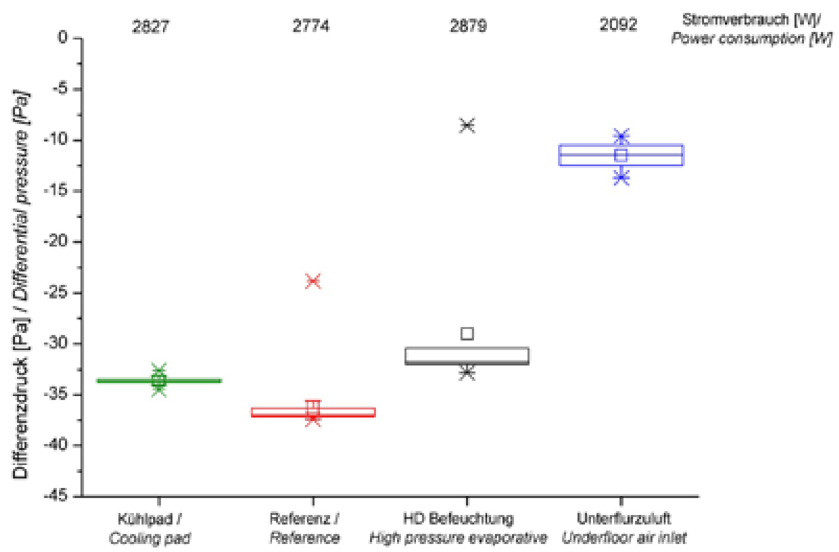
Range of temperatures of inlet air and indoor air

the electricity consumption of the fan was lowest in the underfloor system.

Conclusions

The initial measurements indicate that differences regarding house climate parameters and consumption benchmarks exist between the various air supply and cooling systems, despite otherwise identical construction and installation in the compartments. However, more definite statements can only be made after the summer period is over so as to properly consider all phenomena which may affect cooling efficiency, house air quality, animal welfare, cost effectiveness and functionality either individually or cumulatively. In each case, the results of one practical farm will complete the picture of the various systems, e. g. geothermal heat exchanger, underfloor air supply and high pressure humidification.

Fig. 4



Differential room pressure at fan capacity of 100 % during four hours

Literature

[1] TierSchNutztV (2009): Tierschutz-Nutztierhaltungsverordnung as introduced into law on 22nd August, 2006 (BGBI. I p. 2043) and amended through Article 1 of the act of 1st October, 2009 (BGBI. I S. 3223).

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Disclosure of Funding

Funding for the project is provided by the Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV) via the Bundesanstalt für Landwirtschaft und Ernährung (BLE). Funding ref. (FKZ): 2808HS042.