Wolfgang Büscher, Bonn

Avoiding Heat Stress

Constructional and Technical Measures in Pig Houses

The heat stress problems of last summer left a lasting impression. While the inside pig house temperature was increasing from day to day, feed intake and production levels were decreasing correspondingly. By taking various constructional and technical fundamentals into consideration, farmers could protect pigs against the heat stress situation in most cases. The first evaporation cooling systems tested by the DLG are currently available.

Prof. Dr. Wolfgang Büscher is head of the section "Livestock Technology" at the Institute of Agricultural Engineering at Bonn University, Nussallee 5, 53115 Bonn, Germany; e-mail: *Buescher@Uni-Bonn.de*

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In high ambient temperatures, thermoregulation in pigs is based mainly on the evaporation of water from the respiratory tract (latent heat loss). In a temperature range that varies in extent with the age of the animal, its thermoregulation, i.e. the regulation of deep body temperature, is largely a passive and automatic process. Heat stress is defined as a state of physiological strain in which animals are no longer able to regulate their heat balance passively [3]. They are unable to dissipate their body heat to the degree required for high production levels (for growth or lactation).

Physiological basics

Animals react to heat stress with a number of adjustments. These usually include increased respiration rates, increased water consumption and depressed feed intake. Under such conditions, pigs usually make wallows - given the opportunity to do so - in order to cool themselves by transferring heat into the ground. Lactating sows react to heat stress with a marked fall in milk production, but fattening pigs reduce production, too [4]. As in other situations of stress, pathogens are much more infectious to weakened organisms.

Building and Technical Causes of Heat Stress

Even solid buildings do not offer a general protection from heat loads. Buffering temperature changes better than other buildings, they have certain advantages during the transitional seasons, but under the impact of solar radiation the building envelope may heat up considerably and give off heat to the interior. Therefore, proper thermal insulation is an important preventive measure that minimises heat infiltration into the building through roof and walls during the summer.

Especially dark roof surfaces heat up considerably. In naturally ventilated livestock houses, therefore, additional thermal insulation of the roof can in many cases help to avoid high inside temperatures. Regrettably, few livestock units are greened or lined with trees although this would be thermally advantageous during the summer due to the effect of the shadow. English Ivy or Boston Ivy growing on the exterior of a building are thermally advantageous and do not cause structural damage.

During the summer, the purpose of ventilation is to remove heat from the livestock house [2]. Common technical causes of heat stress are ventilation systems with insufficient airflow rates or, in naturally ventilated buildings, undersized free cross-sectional flow areas.

Raising Volume Rates

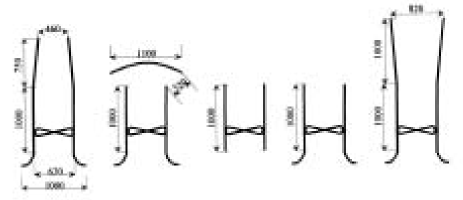
The fans commonly used in livestock houses with mechanical ventilation are of the low-pressure axial flow type. The airflow rates of such fans are strongly affected by pressure conditions. If fans operate against higher system resistance than planned, the desired airflow rates are not attained. By measurements of pressure difference, it is possible to determine whether a fan is suitable for a specific livestock house and for the resistance of the ventilation system.

High pressure resistance may have several causes. In many cases, air velocities in the air ducts are too high, or the cross-sections of the ducts are too small. Air velocities in fresh air ducts should not be higher than 4 m/s.

Exhaust duct design must fulfil the relevant legal requirements. Unless legally required to be higher than 7.0 m/s, exhaust air velocity at the outlet may be lower than that. Each obstruction in the airflow causes resistance and restricts airflow. *Figure 1* shows the impact of duct design on volume rate [5]. Sharp turns and rapid contractions in the ducts are equally problematic.

Volume rates can also decrease due to dust and dirt accumulating anywhere in the ventilation system and tightening free cross-sectional areas. Therefore, the mesh guards of fans and the insides of the perforated ceiling plates should be cleaned at regular intervals (after each production period, if possible).

Additional maintenance may become necessary in the case of a strong fall of poplar downs in the early summer. Porous ceilings



Drehzahl Rotation	min^{-1}	821	814	790	805	832
Leistungsaufnahme Power consumption	W	390	390	403	401	378
Volumenstrom Volume rate	m^3/h %	4870 68	5090 71	6620 100	7410 109	10930 127
Spezifischer Volumenstrom Spec. Volume rate	m^3/kWh %	15 050 70	15 620 73	21 390 100	23 470 110	28 920 135
Spezifische Leistungsaufnahme Spec. Power consumption	$W / 1000\ m^3 h^{-1}$ %	66,4 42	64,1 37	46,8 100	42,6 91	34,6 74

Fig. 1: Volume rate and energy consumption, depending on guidance construction (standard = 100 %, grey background, distances in mm)

are particularly susceptible to damage because they cannot be cleaned from above. Therefore, a layer of mineral wool is usually installed as a dust filter. Under normal conditions, decreases in airflow rates resulting from dust infiltration during several summers are barely detectable [1]. However, the dust layer is likely to clog if moist air flows upwards into the filter during cleaning or while the livestock house is empty. In buildings with porous ceilings, the negative pressure ventilation system should therefore be in operation at all times.

Impact of Fresh Air Ducting

In the summer, fresh air should not be drawn from attics. Attics are usually not aired sufficiently, so the infiltration of heat would be virtually unavoidable. A number of summer measurements conducted by the author have shown that attics may heat up to more than 40 °C under roofs exposed to strong solar radiation. An ideal solution is one that allows a choice by means of a butterfly valve:

- from the attic during the winter;
- directly from outside (from the shade) during the summer.

However, to avoid problems resulting from strong wind when air change is low, the air should first be conducted through a service or entrance room or a service alley. Passing through these areas, the air usually also cools down slightly. It is particularly advantageous to conduct fresh air through an underfloor duct in the foundations of livestock house, e.g. beneath the central service alley. Drawn in on one end wall, the fresh air flows through the duct beneath the service alley before entering the service alley at the opposite wall of the building. The air is then distributed to the pens via the service alley. Summer measurements have shown that the temperature of air passing through a 30 m air tunnel at a velocity of 3.0 m/sec was reduced by 3.0 Kelvin. Assuming an air volume rate of 20,000 m^3/h, this was the equivalent of a cooling capacity of more than 20 kW! This cooling capacity is available at the price of a 10 Pa increase in flow resistance, i.e. the resulting costs of maintaining airflow. A heating capacity of similar proportions may be expected if this type of air ducting is used during the winter, too. These interrelations bear resemblance to the familiar Underground Thermal Energy Storage (UTES) systems in which fresh air is conducted through ribbed tubes into the soil, but the construction costs effort for UTES is much higher.

Use of Cooling Technology

During the summer, many farms give relief to their livestock by installing evaporative cooling systems with open water surfaces in service alleys or in central fresh-air ducts. The cooling effect of this technique also depends on contact time and on the moisture-holding capacity of the fresh air. Temperature decreases by 2 to 3 Kelvin are possible with short contact times. However, the decisive parameter in thermoregulation is the heat content (enthalpy) rather than temperature. Moistening (evaporative cooling) does not lower the enthalpy of the air. If the air becomes too humid (> 85 %; cf. *Tab. 1*), this hampers the animals' latent heat dissipation. To make sure that the moisture-carrying capacity of the air is not overestimated, the controls of the cooling system must be equipped with an air humidity measuring system.

A rather costly solution is the use of built-in pressure lines with jets for spray moistening or fogging. Droplet size and water amount must not be increased so far as to moisten surfaces within the building. The only effective means of preventing this from happening is the use of high pressure systems. So far, there has been very little experience with this solution regarding the relation between cost and benefits. The first DLG-approved evaporative cooling systems (high pressure systems) had a chance to prove their efficiency during the summer of 2003 [6].

Production level	Inside temperature Minimum °C	Optimum[1] °C	Rel. humidity Minimum %	Maximum %	Optimum %
Lactating sows including piglets	18	19 - 21			
Piglets < 2 weeks	28[2]	30 - 33[2]			
> 3 - 4 weeks	24[2]	26 - 30[2]			
> 5 - 8 weeks	20	22 - 26			
> 9 - 12 weeks	18	22 - 20	40	85	60 - 80
gilts, pregnant sows, boars	12	15 - 22			
Young and fattening pigs over 4-months	14	18 - 22			

[1] With straw bedding temperature can be fixed 2 Kelvin lower
[2] as area heating system for piglets

Table 1: Optimum level and critical threshold of temperature and relative humidity in pig houses

Conclusion

Heat stress in pigs can be avoided if a few fundamentals of building construction and technology are taken into consideration. It is important to enable the ventilation system to fulfil its summer task of removing heat from the barn. Once all measures of avoiding heat infiltration and of raising air flow rate have been exhausted, cooling technology can be used. Cooling systems differ with regard to cost and performance. Before investment, farmers should inform themselves thoroughly about the prospective solution regarding its capacities and its adaptibility to the barn equipment already in use.

Literature

Books are identified by •

[1] *Bartussek, H. und A. Hausleitner*: Porenlüftung 1. Arbeitsblatt Bauwesen, BVA-Gumpenstein (Hrsg), Irdning (Österreich), 1979

[2] DIN 18 910 - Wärmeschutz geschlossener Ställe. Wärmedämmung und Lüftung, Planungs- und Berechnungsverfahren. Beuth Verlag, Berlin, 1992

[3] *Kirschner, K. et. al.*: Klimatechnik in der Tierproduktion, VEB Verlag Berlin, 1976, S. 79-109

[4] *Leuschner, P. et. al.*: Lüftung von Schweineställen. AID-Heft 1067, AID Verlag, Bonn, 1996

[5] *Pedersen, S.*: Zu- und Abluftführung aus dänischer Sicht. Tagungsschrift des Förderkreis Stallklima 1999, Tagung in Iden, Vertrieb LK Hannover, 2000

[6] *Niethammer, F.*: "Möller GmbH -Befeuchtungskühlung BFK 1", DLG Prüfbericht 5200, DLG Frankfurt, 2003