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Computing the Summer and Winter Air Volume Flow Rates from Physiological Data in accordance with DIN 18910 - 1

With rising energy costs the demand for conscientious engineering, precise construction and professional management of ventilation and heating systems in animal houses is constantly growing. The methodical procedures for calculating these ventilation rates are described here. A case study on lactating sows shows the relationship between summer and winter ventilation rates and litter sizes and piglet weights. The example illustrates that with regard to these interdependencies, the air volume rates required are significantly higher than currently recommended. Simple software programs could help take individual conditions better into account.

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Keywords

Climatization, ventilation, energy balance

Literature

[1] CIGR (Working Group): Report I of Working Group on Climatization of Animal Houses. Scottish Farm Building Investigation Unit, Aberdeen, 1984
[2] DIN 18 910-1 : Wärmeschutz geschlossener Ställe - Wärmedämmung und Lüftung - Teil 1: Planungs- und Berechnungsgrundlagen für geschlossene zwangsbelüftete Ställe, 2004

In view of current legal and socio-political developments, energy prices and costs are rapidly gaining in importance. In this context, the planning and dimensioning of ventilation systems have a great influence on the consumption values in the livestock buildings to be built. Calculating summer and winter volume flow rates according to DIN 18 910-1, however, is a difficult and error-prone matter. In order to achieve greater transparency and to facilitate solutions for individual livestock buildings, this text presents not only the relevant calculation method, but in looking at a case study with farrowing sows, it also considers various farm-specific conditions and their planning consequences.

Calculation method for physiological data

The calculation methods currently used for determining the sensible heat dissipation of livestock and the required air volume flow rates under summer and winter conditions in closed livestock buildings (as a prerequisite of heat balancing) are described in Report 1 of the CIGR Working Group "Climatization of Animal Houses" [1]. This report is also the basis of DIN 18 9101 [2] as well as nearly all relevant guidelines used in our European neighbouring countries with climatic conditions, livestock keeping methods and livestock races more or less the same as in Germany. For a general understanding of the calculation method, a case study of a sow with piglets is used to illustrate the necessary calculation steps and to present the formula for calculating the relevant physiological data and, deriving therefrom, the air volume flow rates:

Step 1:
The following facts have to be taken into account when calculating the total heat dissipation of a sow and her piglets:

In physiological terms, the total heat dissipation Φ_{tot} (Greek, pronounced 'phi') of the sow is the sum of the maintenance component $\Phi_{maintenance}$ and the milk yield component $\Phi_{lactation}$.

Depending on the assumed live weight m, the following correlations apply in this example:

Φ_{tot} [W] = $\Phi_{maintenance} + \Phi_{lactation}$

$\Phi_{maintenance}$ [W] = $4{,}85 \cdot m^{0{,}75}$ and

$\Phi_{lactation}$ [W] = $26 \cdot Y_{milk}$

Depending on the assumed live weight m, the following correlation for piglet rearing is assumed to apply in this example:

$$\Phi_{tot} = 29 \cdot (m + 2)^{0{,}5} - 40 \quad (A.1)$$

with

- Φ_{tot} total heat dissipation in Watts (W);
- m live weight in kilogrammes (kg);
- Y_{milk} milk yield of the sow in kilogrammes per day (kg/day).

Step 2:
As the total heat production (sum of all components) depends on the ambient temperature t, the following correction factor F has to be calculated next to be multiplied by the total heat dissipation in the next step:

$$\Phi_{tot,\, cor} = F \cdot \Phi_{tot} \quad (A.2)$$

$$F = 4 \cdot 10^{-5} \cdot (20 - t)^3 + 1 \quad (A.3)$$

with

- $\Phi_{tot,\, cor}$ corrected total heat dissipation in Watts (W);
- F correction factor;
- t ambient temperature in degrees Celsius (°C).

Step 3:
In this calculation, the formula reflects the fact that the sensible heat dissipation Φ_{sens} decreases with increasing ambient temperatures (due to the increasing proportion of evaporative heat dissipation):

$$\Phi_{sens} = \Phi_{tot,\, cor} \cdot [0{,}8 - 1{,}85 \cdot 10^{-7} \cdot (t + 10)^4] \quad (A.4)$$

with

- Φ_{sens} sensible heat dissipation, in Watts (W);

Step 4:
The rest, reduced by the sensible heat, corresponds to the latent heat Φ_l. Taking into account the evaporative energy bound in the water (680 Wh kg^{-1}), this can be offset against the amount of evaporated water X (water vapour dissipation) according to the following formula:

$$\Phi_l = \Phi_{tot,\, cor} - \Phi_s \quad (A.5)$$

with

- Φ_l latent heat in Watts (W);

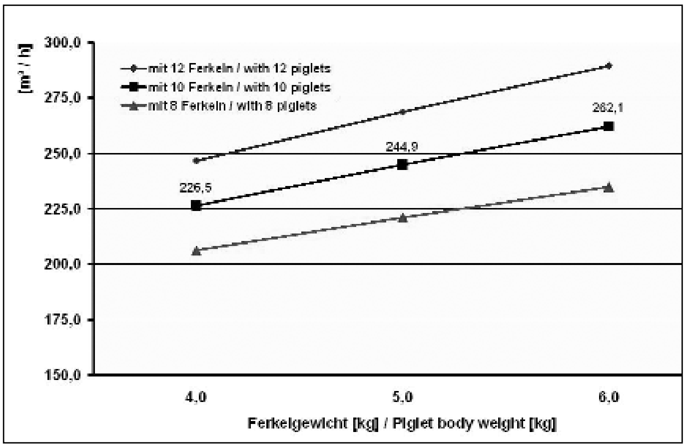

Fig. 1: Summer air volume flow for lactating sows depending on litter size and piglet weight for an examplary barn (KTBL ZS 10003)

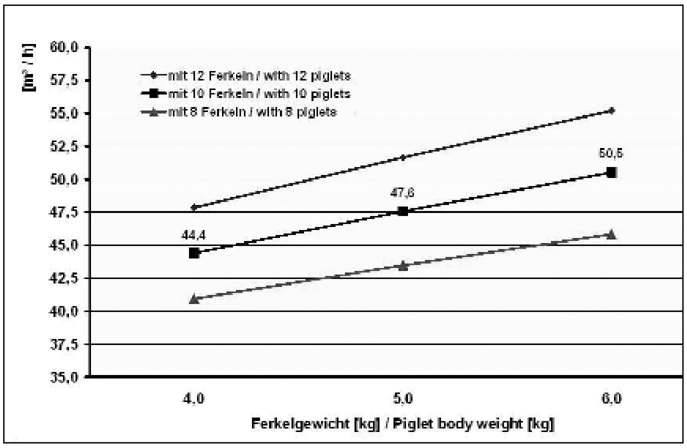

Fig. 2: Winter air volume flow for lactating sows depending on litter size and piglet weight for an examplary barn (KTBL ZS 10003)

$\Phi_{tot,\ cor}$ corrected heat in Watts (W);
Φ_{sens} sensible heat in Watts (W).

$$X = \Phi_l \ / \ 0{,}68 \qquad (A.6)$$

with
X amount of evaporated water in grammes per hour ($g\ h^{-1}$);
Φ_l latent heat in Watts (W).

Step 5:
In physiological terms, the production of carbon dioxide is a function of the total heat dissipation $\Phi_{tot,\ cor}$. It is usually calculated with reference to the "corrected" total heat dissipation (equation A.2).

The carbon dioxide production is calculated using the following formula which takes into account two gas constants:

$$\dot{K}_m = \Phi_{tot,\ cor} \bullet 0{,}163 \bullet 1{,}81 \qquad (A.7)$$

with
$\dot{K}_m$ carbon dioxide production in grammes per hour ($g\ h^{-1}$);
0.163 CO_2 production in litres per hour per Watt (following [1]);
1.81 density of CO_2 at 20 °C and 1000 hP ($g\ l^{-1}$).

As these equations are valid for both summer and winter, calculations to determine the required air volume flow rates in winter conditions must be carried out down to the level of carbon dioxide production. In summer conditions, it is only the production of sensible heat that is of interest in calculating the summer volume flow rate required to remove excess heat from the livestock building.

Calculations of the physiological data and the resulting volume flow rates for pig keeping have to take the following limiting conditions into account (*Table 1*) [2].

Case study

Because of different requirements in terms of physiological performance, the calculations of the air rates for lactating sows and their piglets require two separate calculations (one for the sow and one for the piglets). The calculations are easier if the total heat dissipation ?tot of the sow and the piglets are determined together in a single calculation:

$$\Phi_{tot} = \Phi_{maintenance\ (sow)} + \Phi_{lactation\ (sow)} + \Phi_{piglets}$$

The advantage is that the subsequent calculation steps (see above) have to be carried out only once. From a thermotechnical point of view this makes sense because the conditions (interior temperature and relative humidity as well as building effects) are the same for sow and piglets. Of course, it is necessary to supply a sufficient amount of heat to the piglets in their resting area. It is not useful, however, to perform the calculations for a single animal because in that case the building effect is distorted. Therefore, the following example calculations were carried out using the AEL Indoor Climate Program (version 1.2, October 2007) (*Table 2*):

Figures 1 and 2 show the summer and winter air volume flow rates for a sow with a live weight of 250 kg and with a varying number of piglets of different weight. Under practical conditions, the weight of piglet will depend primarily on its age.

Taking into account the heat dissipation of the piglets as well, it consequently becomes clear that the required summer air volume flow rates for farrowing sows are much higher than in the currently available recommendations and calculation examples of DIN 18 910-1. If it is impracticable to carry out detailed calculations for the respective livestock building and for the current livestock performance, the rule of thumb for an adequate summer air volume flow rate is 250 m^3 per hour per sow.

- The complex regulations of the DIN 18 910 – 1 "Wärmeschutz geschlossener Ställe" construction standard are explained comprehensibly and in some detail in AEL-Heft 17 / 2007 „Berechnungs- und Planungsgrundlagen für das Klima in geschlossenen Ställen" (Basic Planning Considerations and Calculations for the Climate in Closed Livestock Buildings")
- All required calculations - also for all other productive livestock – can easily be carried out with the AEL Indoor Climate Program (AEL-Stallklimaprogramm).

AEL Heft 17 and a demo version of the Indoor Climate Program are available for download at *www.ael-online.de* free of charge.

Table 1: Calculation specifications for deriving the physiological values with DIN 18 910 -1 [2]

Animal species/production phase		**Calculation method**
Pigs		
piglets and fattening pigs		Φ_{tot} [W] $= 29\,(m + 2)^{0,5} - 40$
pregnant sows	maintenance metab.	$\Phi_{maintenance}$ [W] $= 4{,}85 \bullet m^{0,75}$
	embryonic growth	$\Phi_{pregnancy}$ [W] $= 8 \bullet 10^{-5} \bullet p^3$
lactating sows	maintenance metab.	$\Phi_{maintenance}$ [W] $= 4{,}85 \bullet m^{0,75}$
	lactation metabolism	$\Phi_{lactation}$ [W] $= 26 \bullet Y_{milk}$
Y_{milk}: milk yield in kg/day		p: day of gestation

Table 2: KTBL-type barn

Conditions	**a**	**in summer**	**in winter**
indoor temperature	^0C	30	18
rel. humidity	%	70	80
correction factor r		1	1
summer temperature range	^0C	< 26	
admissible summer temp. difference	K	3	
winter temperature range	^0C		-10
(336 producing sows, 72 farrowing places, calculated as a one-room barn)			