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Ventilation problems in open barns for livestock

Outdoor climate, open-front and open barns have established themselves in the last years not only on cost grounds. However the concept brings with it a series of disadvantages. Especially on warm, low-wind days ventilation problems occur which can have a negative effect on animal performance and health. Heat entry via the roof of such building, with up to 300 watt/m² of roof area is higher that the heat given off by the cattle themselves. This output must also be considered in the planning of ventilation areas and equipment for support ventilation.

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Keywords

Heat production, heat entry, heat stress, air rate, air velocity, supporting ventilation

Since the end of the 80s the trend in cattle housing has moved from outdoor climate barn, open front barn and back to the open building (Louisiana barn). Alongside building cost and time savings the moves are mainly based on welfare-based production. While winter difficulties are nowadays to a large extent under control further problems have appeared with these types of buildings, also caused by the high yielding livestock and now mainly occurring in summer. Weather situations where air exchange is low with high temperatures reduce the exchange on naturally ventilated barns to such an extent that the animals suffer heat stress.

Neccessary airflow rates

According to DIN 18910 (1992) the necessary airflow rate for a 700 kg dairy cow in summer with an outside temperature of 30 °C and a permissible temperature increase within the barn is from 3 K 375 m³/h. The information regarding flow of sensible heat in summer assumes milk production performance of 5000 kg/cow•year. Higher production is not taken account of in summer. Calculation basis for the heat flow as given in DIN 18910 is the report of the CIGR working group "Climatization of animal houses", 1984. Accordingly a dairy cow with a performance of 10 000 kg under these conditions has a calculated necessary airflow rate of 477 m³/h. However, there are substantial differences existing within the lactation (*table 1*).

Table 1: Necessary air rates for a cow with 700 kg weight, 10 000 kg milk yield, 30 °C, Δt = 3 K

Performance groups	Lactation third 1.	2.	3.	Dry-cows
Summer air rate in m³/h	569	473	412	334

The thermo-neutral area for dairy cow lies, however, much lower than the value applied for the ventilation calculation, namely between 4 and 16 °C. Up to around 22 °C the feed conversion becomes worse and feed intake is reduced and milk performance drops. With an ambient temperature of 30 °C performance sinks by around 20%. At the same time substantial fertility problems, something high performance cows are especially affected by, appear.

In association with ambient temperature the total heat produced by a high performance cow partially as water vapour, partially as so-called "sensible" heat, is directly given off (*table 2*). In the range within which the cow feels comfortable, i.e. up to about 25 °C, the necessary airflow rate lies by 890 m³/cow•h.

Influence of non-insulated roofs

The calculated summer air rates according to DIN or CIGR are based only on the heat production of the animal in association with the ambient temperature. Barn influences are not considered. Because "free ventilation" is primarily taken account of in the planning of outdoor climate barns, the influences of the building, especially the heat entry via the roof, has additionally to be considered.

Per average hour on sunny days global radiation values of up to 800 watt/m² are measured. If one assumes that around 30% of this heat radiation is reflected then the remaining 70% is applied on both sides of the roofing panels and can mean a heat entry into the barn of up to 300 watt/m² roof area. This applies to roofs with grey panels and where the roof is red coloured such values can be around 10% higher. Depending on the outdoor temperature and the wind velocity the barn roofs reach temperatures of over 60 °C on the outer surface.

Table 2: Heat and water vapour production of a high-yield dairy cow in the first time of lactation

Barn temperature in °C	Heat output in W	Water vapour production in g/h
5	1546	600
10	1380	605
20	1120	885
25	895	1200
30	540	1640
35	60	2100

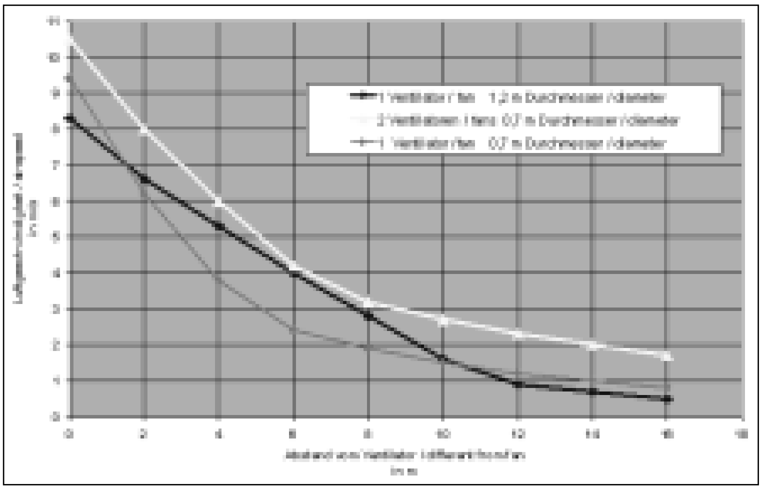

Fig. 1: Throwing range of different fans and arrangement

Roof temperatur in °C	35	40	45	50	55	60
Heat entry in W/animal	132	264	396	528	660	792
Necessary airflow rate in m^3 at 30 °C	139	278	417	556	695	834

Table 3: Heat entry of non-insulated roofs and necessary air rates for removing additional heat

Wind velocities in m/s	0,5	1	2	3	4
Inlet and exhaust air areas in m^2/cow	1,57	0,79	0,39	0,26	0,20

Table 4: In- and exhaust air surfaces for non-insulated houses depending on wind velocity at a maximum air rate of 1700 m^3/dairy cow • h

Typical cubicle buildings such as two and three row ones have a roof area from 7 to 9.5 m^2/cow place. If one takes into account a k value for the roof panels of 3.3 the roof temperatures of 35 to 60 °C give an additional heat entry from 132 to 790 watt per cow (*table 3*) as convection. The heat radiation is not considered here.

According to outdoor temperature, sun radiation, animal performance and lactation stage, in outdoor climate barns in summer an airflow rate between 350 and 1700 m^3/cow and hour is thus necessary to achieve a good barn climate.

Influence of the air velocity on the animals

While with pigs in summer air velocities in housing areas of 0.5 m/s should not be exceeded to any extent, cows are absolutely tolerant compared with this. With high temperatures they even prefer high air velocities for more efficient giving-off of heat and moisture. Air velocities in-barn of up to 5 m/s don't represent any problem where surrounding temperatures are high. Thus increase of heat production with an air velocity of 0.8 m/s represents around 6%, at 5 m/s already 20%. Information from the USA shows that in the vicinity of the animal in summer an air velocity from 1 to 2.5 m/s should be reached. This represents an increase in heat production from 7.5 to 12%.

Inlet and exhaust air areas

From the information on necessary air exchange rates results inlet and exhaust areas appropriate for summer. Because of the no longer existing temperature difference between inside and outdoors the increase has almost completely come to a stop and the necessary ventilation air exchange can only be realised through the wind. To what extent this is effective within the barn depends on its location and positioning regarding the prevailing wind, pressure losses at entry and airflow obstacles within the building. The occurring pressure loss can be reckoned at around 40% with inlet and exhaust areas then calculated as in *table 4*.

It is clear from these calculations that results up until now on inlet and exhaust air areas (KTBL, ALB Bavaria) for high performance livestock in barns in non-insulated roofs are no longer sufficient by a considerable margin. Simultaneously there results that that modern buildings, especially barns with stall widths of over 20 m, must have an open side wall area from 2.5 to 3 m height in order to still reach the required air exchange rate with an outdoor wind velocity of 1 m/s.

Additionally, however, one must also take account of the fact that with these calculations the air velocity in the vicinity of the animals already sinks under 1 m/s and thus the comfort of the animal at temperatures over 20 °C is impaired. Therefore free ventilation on warm days fails where exterior wind velocities are under 2 m/s.

Support ventilation

In dairy farming three systems of support ventilation are applied:

Circulation system:
Here, moveable fans are fitted on the barn walls and interior. The air inside the barn is thus agitated through oscillating movement of the fans leading to a cooling effect on the skin of the animals. However this system does not sufficiently encourage air exchange.

Tunnel ventilation:
Here several large fans are fitted onto a gable wall in the barn with the whole barn enclosed except for a defined air inlet on the directly facing wall. The fans produce a suction effect so that air streams through the whole stall from gable to gable. Flow velocity here is up to 2.5 m/s. This system, however, is often unsuitable with typical cross sections in German cattle houses because fan power of up to 4000 m^3/cow•h would be required.

Step by step system:
This utilises the suction as well as the pressure area capabilities of the fans. Through a row of several large fans mostly positioned along the length of the barn, the air is transported through the barn step by step. With this, different air velocities in the vicinity of the animals and a sufficient exchange of air are realised.

The tunnel ventilation and the step-by-step system enable in summer the transport of exhaust air out of the barn. This creates a possibility for precisely reducing emissions where there may be nearby domestic housing. However the efficacy of the fans can be increased when they are blowing out exhaust air according to the prevailing wind.

Often in practice large fans with diameters of up to 1.40 m are used. These have the advantage of an efficient energy-performance-relationship with high air volume flow. In most cases, however, so-called "slow runners" are used with relatively short air projection distances. With the application of only one large fan there is additionally the problem of the need for regulation at low air rates. This also leads to an increased electricity consumption based on the performance achieved. Cost efficient is the application of two to three medium sized fans (diameter 0.7 to 0.9 m) to be judged as a block. The advantages over single hanging fans are:

- no rpm control required
- better shallow ventilation over the individual function areas is possible
- increasing of the air projection distance (*fig. 1*).