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Minimum summer ventilation flow for high performance dairy cattle

A sufficient minimum ventilation flow in summer and insulated roofing are among the important factors offering good welfare and acceptable ammonia emissions, especially in housing for high performance dairy cows. The following observations are aimed at helping the authorities, planners and farmers in identifying welfare-oriented and low emission minimum summer ventilation flows.

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Keywords

Air velocity, summer, dairy cows

Literature

Literature details are available under LT 02504 at httpi/www.landwirtschaftsverlag.com/ landtecMocal/fliteratur.htm

According to the fourth ordinance in applying the Federal Emission Protection Statute (Ordinances regarding facilities requiring planning permission - 4. BImSchV) permission according to pollution statutes, in some cases with tests for environment suitability is required in the applicable for cattle (in part from 250 head) and calves (in part from 300 head).

Minimum summer ventilation flow

According to DIN 18910
A cow's demands from her environment grow along with increasing milk output. Aspects of welfare-oriented housing are removal of superfluous heat and sufficient fresh air supply.

According to the summer temperature card of DIN 18910 [1] there are two temperature zones in Germany <26 °C ($\Delta\vartheta$ = 4 K) and ≥26 °C ($\Delta\vartheta$ = 3 K). The temperature difference 3 or 4 K is here the permitted animal welfare relevant housing interior temperature increase compared with outer temperature. With outer temperatures of 30 °C in summer DIN 18910 gives sensible amounts of heat ($Q_{ST.S}$) only for annual lactations of 5475 kg/cow/year for the determination of minimum summer ventilation flows.

According to Heidenreich
With reference to DIN 18910 he determined the minimum summer ventilation flow analogue to increases for winter (5% per 1000 kg milk) and tested these in 1930 dairy housing [2].

According to the 1984 CIGR report
The CIGR report [3] contains explicit information on sensible heat from milk cows (up to 700 kg) with 10 kg/d milk production (3650 kg milk), with 15 kg/d (5475 kg milk) and with 20 kg/d (7300 kg milk). The minimum summer ventilation flow can be determined for high performance cows with equations 1 to 4.

Total heat production Q_{tot20} [W] at 20 °C

$$Q_{tot20} = 5{,}6 \cdot m^{0{,}75} + 22 \cdot Y + 1{,}6 \cdot 10^{-5} \cdot p^3 \quad (1)$$

where m = liveweight
Y = milk production kg/d
p = pregnancy stage in days (140 days)

Total heat production Q_{tot30} [W] at 30 °C

Temperature correction factor F

$$F = 4 \cdot 10\text{-}5\ (20 - t)3 + 1 \quad (2)$$

Where t = temperature in°C

$$Q_{tot30} = F \cdot Q_{tot20} \quad (3)$$

Sensible heat $Q_{ST.S}$ [W]

$$Q_{ST.S} = Q_{tot} \cdot [0{,}8 - 1{,}85 \cdot 10^{-7} \cdot (t + 10)^4] \quad (4)$$

Table 1: Minimum summer ventilation flow according to the CIGR report 1984

Liveweight / Milk production	[kg] / kg/a	5000	6000	7000	600 / 8000	9000	10000	11000	12000
Based on 365 d	[kg/d]	13.7	16.4	19.2	21.9	24.7	27.4	30.1	32.9
305 d	[kg/d]	16.4	19.7	23.0	26.2	29.5	32.8	36.1	39.3
Total heat$_{30}$	[W]	983	1041	1099	1157	1215	1273	1330	1388
Sensible heat$_{30}$	[W]	321	340	359	375	394	412	424	450
Minimum summer ventilation flow	[m³/h cow]								
$\Delta\vartheta$ = 4 K		254	269	283	*296*	*311*	*326*	341	355
$\Delta\vartheta$ = 3 K		338	358	378	*395*	*415*	*434*	454	474
Liveweight	**[kg]**				**700**				
Total heat	[W]	1063	1121	1179	1237	1295	1352	1410	1468
Sensible heat	[W]	347	366	385	404	423	441	460	479
Minimum summer - ventilation flow	[m³/h cow]								
$\Delta\vartheta$ = 4 K		274	289	304	*319*	*334*	*349*	364	379
$\Delta\vartheta$ = 3 K		366	385	405	*425*	*445*	*465*	485	505

Minimum summer ventilation flow at $\Delta\vartheta$ = 3 and 4 K

$$V = Q_{ST.S30} / \Delta\vartheta_{zul} \cdot c_{pl} \cdot \rho \quad (5)$$

where c_{pl} = 0,28 Wh/Kkg and ρ = 1,13 kg/m^3

$\Delta\vartheta_{zul}$ = 3 or 4 K

The minimum summer ventilation flows per cow at 30 °C in relation to milk production and liveweight for $\Delta\vartheta$ = 3 K and 4K, without heat production through roof are given in *table 1*. The minimum summer ventilation flows determined by Heidenreich are 1% greater.

According to Bartussek

Bartussek [4] envisaged for a 600 kg liveweight cow a minimum summer ventilation flow of 480 m^3/h animal and 560 m^3/h animal for 700 kg liveweight cow with a lactation of only 5200 kg/cow and year to be expected.

According to Pedersen

The total heat production Q_{tot20} at 20 °C is identical in the Pedersen work [5] and the CIGR report. The formula (6) for the sensible heat differs.

$$Q_{ST.S} = (Q_{tot20} / 1000) \cdot (1000 \cdot 0{,}96 \cdot 0{,}71 - 0{,}407 \cdot t^2) \quad (6)$$

According to the CIGR report 1984 the sensible heat is around 1 % lower than that according to Pedersen.

Experiences from the USA

In the USA dairymen use fans to reduce heat stress in their cattle. The systems differ between tunnel ventilation and a circulation system. Air velocities at the cow for an optimum cooling effect are calculated at 1.0 to 2.5 m/s.

In buildings 3 m high and 12 m wide air velocities for tunnel ventilation of up to 2630 m^3/h animal are aimed at.

Naturally ventilated buildings

Outdoor climate buildings built sideways to the prevailing wind direction with minimum eave heights of from 3.50 to 4 m, minimum roof slope of 24°, ridge air outlets totalling 0.15 m^2/cow, non-insulated roof and roof overhang of up to 1.5 m were fitted with windbreak nets and, more recently, roller windbreaks from a base side wall height of 0.30 m [2, 7].

Using natural air currents as cross ventilation means that a resistance value c = 0,6 [8] and a site specific maximum outdoor air velocity of 1 m/s should be calculated for where no meteorological evaluation is available.

According to the building installations, and for those over 20 m width the c-value should be determined through measurements.

Table 2: Recommended air flow in cattle housing

Temperature [°C]	Air velocity [m/s]
≤ 10	0.1
13	0.1
16	0.2
19	0.3
20	0.4
21	0.5
22	0.6
23	0.7
24	0.8
25	0.9
26	1.0
27	1.2
28	1.3
30	2.5

Four rows of cubicles, each 1.25 m in width, cross passages after 15 cubicles and an eaves height of 4 m with light openings at 3.70 m give an air inlet area per side of 3.70 m • 1.40 m = 5.18 m^2 for four cows, i.e. ~ 1.3 m^2/cow. With an outdoor wind velocity of 1 m/s and a c-value of 0.6 the ventilation flow represents 2800 m^3/h and cow, with 0.5m/s still 1400 m^3/h and cow.

Heat production from roof

To be considered in heat production from the roof are temperatures from 35 to 55°C from an area of from 8 to 10 m^2/cow.

- non insulated roof k = 3.3 W/m^2 K
  Heat production Q_T (transmission heat and Q_R (radiation) with 10 m^2 /roof area/cow and 30 °C interior air temperature:
  Q_T= 165 to 825 W
  Q_R = 50 to 1200 W according to building material and temperature
- insulated roof k = 0.6 W/m^2 K
  Q_T =30 to 150 W

In determining the ventilation flow, heat production (transmission and radiation) through the roof, along with sensible heat, is at least in the case of non-insulated roofing to be considered as cumulative value.

To balance the heat production through the non-insulated roof, four to five times the summer ventilation flow required to meet the physiological needs of the animals is required.

Optimum air velocity at the animal

If the wind velocity increased, the thermoneutral zone borders moved upwards [9]. Depending on the interior air temperatures the following air velocities (*table 2*) are recommended by [6, 10] in cattle housing.

Against heat stress on hot days, ventilation equipment is used which give air velocities from 1.0 to 2.5 m/s and up to 5.0 m/s [11, 12].

Increasing the air velocity up to 4.5 m/s led to a positive correlation with heat production. This almost reached the level of the heat production in the temperature range of 10 to 26 °C [12].

Cooling effect of the air

When applying fans, the cooling effect of the air has to be taken account of (*table 3*) [10, 12].

With air velocities at the animal giving a cooling effect of 3K or many times this, the next-lower summer temperature zone can be selected (CIGR report 1984, table 6.3).

Higher air velocities over wet areas increase emissions, however so that air streams from fans should generally be aimed at the lying area of the animals.

Specific interior volumes

In cattle housing there should be a free interior volume of at least 35 m^3 per cow, giving eaves heights of at least 3.50 m [7]. Outdoor climate housing with 40 to 50 m^3/interior air volume per animal have proved themselves in practice.

Conclusions

The investigation into minimum summer ventilation flows for high performance dairy cows must follow nowadays the CIGR report 1984, because the DIN 18910 does not include the necessary values.

For animal welfare oriented and low-emission ventilation the air volume flow should be directed into the lying areas.

With regard to emissions and animal welfare, especially in low-height animal housing, insulation in the ceiling or the roof skin is recommended.

In renovation of compact buildings, the application of forced ventilation equipment may be necessary. In high summer it must be expected that the cows will seek out the cool lying areas in the housing.

Table 3: Cooling effect of the air

Air velocity [m/s]	Cooling effect [°C]
0.10	0
0.25	0.56
0.50	1.87
1.25	3.33
2.50	5.56
4.50	8.30