# MICROCLIMATE IN COWSHEDS IN FINLAND AND ESTONIA

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## SUMMARY

A series of microclimate measurements were performed in different kinds of cow houses in Estonia and Finland. The number of animals in the structures varied from 30 to 600. Measurements were made in summer and winter conditions with ambient temperatures from –30°C to + 30°C. The results showed that there were differences in microclimate depending on design of structures, outside temperature, wind and ventilation rates. The recommended values for microclimate in the cow structures were mainly within the recommendations.

**Keywords:** microclimate, ventilation, cold, uninsulated, semi-insulated barns, cow houses

## INTRODUCTION

Due to the lower investment, capital and construction costs, cold un-insulated and semi-insulated cow structures have been of interest in recent times. The building cost for the framework and walls are estimated to be about 15% lower in semi-insulated and 35% lower in non-insulated cubicles than in fully-insulated free stalls structures (Jeppsson et al., 2006). In the last 15 years about 310 semi-insulated structures have been built in Finland consisting of about 15 to 40 animal units (Brännäs, 2005). Presently, Estonia has over 60 large semi-insulated structures housing between 300–1000 animal units each (Kivinen et al., 2006), and about 90 new or renovated uninsulated cowshed between 2002 and 2006 (Pajumägi, 2007).

**Table 1.** Nationally acceptable concentrations in dairy animal structures (MMM) and the harmful concentrations limits to humans in Finland (MSAH, 2005)

| Gases | Limits in animal structures (ppm) | Exposure limits to humans | |
|---|---|---|---|
| | | (ppm) | (mg/ m$^3$) |
| Carbon dioxide, $CO_2$ | 3 000 | 5000 (8 hrs) | 9100 (8 hrs) |
| Ammonia, $NH_3$ | 10 | 20 (8 hrs), 50 (15 mins) | 14 (8 hrs), 36 (15 mins) |
| Hydrogen sulphide, $H_2S$ | 0,5 | 10 (8 hrs), 15 (15 mins) | 14 (8 hrs), 21 (15 mins) |
| Carbon monoxide, CO | 5 | 30 (8 hrs), 75 (15 mins) | 35 (8 hrs), 87 (15 mins) |
| Organic dust | 10 mg/m$^3$ | – | 5 (8 hrs), 10 (15 mins) |

Estonia and Finland experience weather conditions ranging from –35 °C to +35 °C. This varying weather prevailing in the winter and in the summer makes it difficult to ensure suitable diurnal microclimatic conditions for the animals in dairy buildings. Poor microclimate in animal structures and high gaseous concentrations can increase the occurrence and severity of certain endemic diseases (Amon et al., 2001). Several authors have shown that gaseous concentrations are often too in high animal structures (Zhang et al. 2005). The European Directive 2001/81/EC on National Emission Ceilings, sets upper limits for the total amount of emissions from each Member State for the total emissions of gases like Sulphur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$), Volatile Organic Compounds (VOCs) and Ammonia ($NH_3$). However, the directive leaves it largely to the Member States to decide which measures to take in order to comply. In Finland the building regulation of the Ministry of Agriculture and Forestry (MMM-RMO C2.2, Table 1) specifies some recommended microclimatic conditions in livestock structures. In addition, the Ministry of Social Affairs and Health in Finland (MSAH 2005, Table 1) and Labour Inspectorate Estonia under the Ministry of Social Affairs have exposure limits for indoor air conditions for workers. In Estonia some guidelines for cow protection in cow structures can be found (RTL, 124, 179. 2002). For workers, indoor microclimatic standards like EVS 839:2003 that deal with indoor air quality for humans and EVS 845:2004 for ventilation are also available. Typically, where recommendations are unavailable, animal structure designers try to go according to the recommendations given by the CIGR commission. For relative humidity (RH) in animal structures, CIGR (1984) recommends maximum and minimum values as a function of indoor temperature, for example, a RH of 50–90% at $0^oC$ followed by a steady decrease of RH to a tolerable range of 40–60% at 30°C. In Finland, the MMM-RMO C2.2 recommends an optimum RH of 50 to 80% and optimum temperature conditions for dairy cows to be between 5–15°C. Lower and upper critical temperatures were proposed to be –15°C to –25°C and 23 to 27°C respectively.

The objective of this research paper was to find out the microclimate conditions of different types of cow structures during varying climate conditions. It will also assess whether these microclimatic conditions meet national recommendations.

## MATERIALS AND METHODS

A series of microclimate measurements were performed in different kinds of cow structures in Estonia and Finland. The number of animals in the structures varied from 30 to 600. The measurements included both summer and winter conditions and the ambient temperatures from –30°C to 30°C. The buildings included uninsulated and insulated structures. Three different types of measurement systems were used. A stationary multiple-sensor measuring station (Fig. 1) and wireless measurement system, both for long period measurements, and a mobile multiple-sensor measurement system for short period measurements. Typical sensor locations of a stationary measurement system are as shown in Fig. 1. A set of temperature, radiative heat, heat flux, relative humidity, ammonia, carbon dioxide, hydrogen sulphide and air velocity sensors were places at 0.5, 1 and 1.5 m heights inside the measuring and data logging station. The stationary measurements were completed with more precise and periodical gas and ventilation measurements. Gas measurements were performed with a Fourier Transform Infrared Spectrometry (FTIR) multi gas analyzer. Measurement of air velocity was done using multiple hot-wire and 3-dimentional ultrasonic anemometers (Fig. 1). These measurements were done in one day and continuous measurements in 1–4 months.

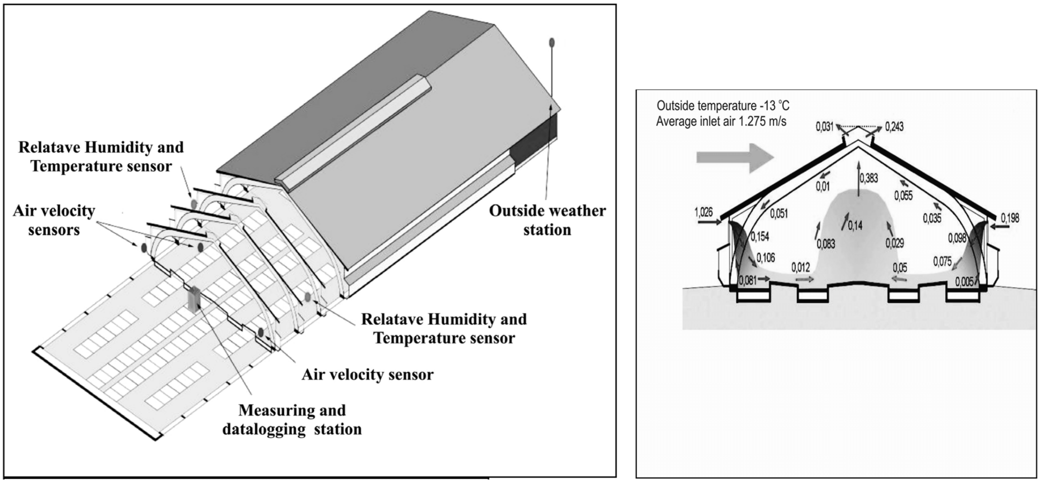


**Figure l.** Measurement set-up and location of sensors for microclimate studies (left). Velocity profile in cowshed (right).

Carbon dioxide balances were employed in the estimation of emissions. The calculations were made based on the conservation of mass and energy in the building, under steady-state conditions. The ventilation flow through the animal structure, $q_v$ in $m^3\ h^{-1}$ the gaseous emissions $E_g$ were estimated according to Eq. (1), where $C_{prod}$ is the production of $CO_2$ in $m^3\ h^{-1}$, $C_{in}$ and $C_{out}$ is the are the $CO_2$ concentrations in the indoor and outdoor air in ppm. $\Delta C_g$ is the difference between the inside and outside gaseous concentrations of the individual gases in ppm.

$$q_v = \frac{C_{prod}}{C_{in} - C_{out}} \qquad (1)$$
$$E_g = q_v \Delta C_g$$

## RESULTS AND DISCUSSION

The intermittent and continuous measurements provided information about typical gas concentrations and microclimates in dairy structures under moderate to extreme winter and summer conditions. All the cow structures except F5 and F6 had natural ventilation (table 2). The differences in cowshed structural designs and manure handling methods contributed to the ventilation and microclimate. Ventilations rates were very variable and airflow velocities were between 0.1 and 0.7 m/s at 1m in the centre of the cow structures (table 2).

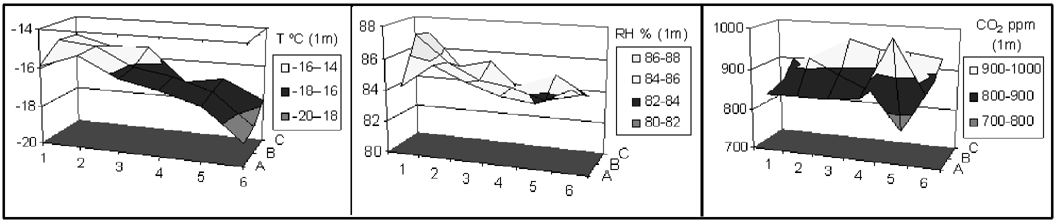


**Figure 2.** Spatial variation in microclimatic conditions in dairy barn (winter, Finland)

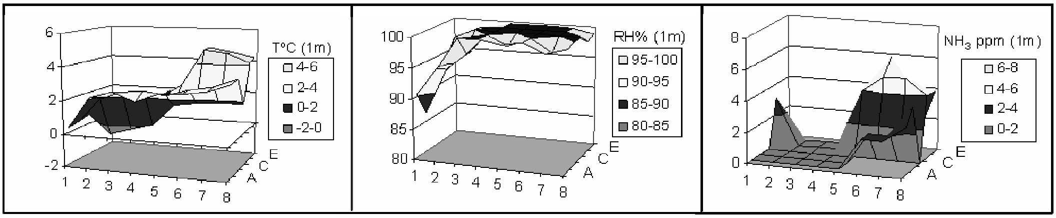


**Figure 3.** Spatial variation in microclimatic conditions in dairy barn (winter, Estonia)

**Table 2.** Microclimate in cow structures in Finland and Estonia. Notation: the place coding is as follows E=Estonia, F=Finland, 1–7=site number, W=winter, S=summer. V is ventilation; Vol is volume of cow structure.

| Place | Cowshed type | Number of Cows | Vol ($m^3$) × $10^4$ | $T_{in}$ (°C) | $T_{out}$ (°C) | $v_{in}$ (m/s) | $v_{out}$ (m/s) | $RH_{in}$ (%) | $RH_{out}$ (%) | $CO_{2in}$ (ppm) | $NH_{3in}$ (ppm) | $CH_{4in}$ (ppm) | V ($m^3$/h) × $10^3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E1W | semi-insulted | 480 | 45 | –1 | –2 | 0.2 | 2.3 | 91 | 74 | 522 | 1.1 | 17 | 616 |
| E1S | | 460 | 45 | 28 | 27 | 0.6 | 2.5 | 39 | 38 | 454 | 1.6 | 8 | 700 |
| E2W | semi-insulted | 500 | 66 | 1 | –3 | 0.1 | 1.7 | 89 | 72 | 775 | 1.6 | 34 | 233 |
| E2S | | 500 | 66 | 27 | 28 | 0.3 | 0.1 | 46 | 40 | 751 | 9.7 | 40 | 262 |
| E3W | semi-insulted | 500 | 53 | 2 | 0 | 0.1 | 0.4 | 87 | 90 | 1171 | 3.3 | 64 | 116 |
| E3S | | 500 | 53 | 29 | 30 | 0.3 | 0.4 | 44 | 37 | 375 | 3.0 | 9 | – |
| E4W | semi-insulted | 600 | 64 | 0 | –4 | 0.1 | 4.2 | 86 | 85 | 854 | 3.2 | 40 | 233 |
| E4S | | 600 | 64 | 28 | 29 | 0.6 | 2.5 | 47 | 47 | 412 | 17.0 | 14 | 783 |
| E5S | semi-insulted | 500 | 53 | 30 | 32 | 0.7 | 1.0 | 38 | 28 | 397 | 2.6 | 11 | 2865 |
| F1W | uninsulated | 55 | 24 | –17 | 11 | 0.1 | 3.8 | 84 | 83 | 856 | 0.2 | 39 | 20 |
| F2W | semi-insulted | 50 | 25 | 1 | –1 | 0.3 | 3.2 | 82 | 68 | 1225 | 15.4 | 42 | 11 |
| F3W | semi-insulted | 95 | 10 | 4 | –12 | 0.1 | 1.4 | 84 | 85 | 1678 | 7.0 | 116 | 13 |
| F4W | semi-insulted | 80 | 11 | 3 | –12 | 0.1 | 1.6 | 84 | 85 | 1678 | 3.5 | 58 | 11 |
| F5W | fully-insulated | 70 | 5 | 8 | –8 | 0.1 | 0.1 | 73 | 74 | 1622 | 3.4 | 110 | 10 |
| F6W | fully-insulated | 60 | 10 | 12 | 1 | 0.3 | 0.7 | 75 | 80 | 1545 | 8.0 | 86 | 9 |
| F6S | | 60 | 10 | 19 | 18 | 1.0 | 0.2 | 54 | 47 | 757 | 2.6 | 20 | 26 |
| F7W | uninsulated | 50 | 6 | 6 | 3 | 0.1 | 2.9 | 91 | 86 | 550 | 1.3 | 17 | 55 |
| F7S | uninsulated | 50 | 6 | 29 | 26 | 0.2 | 2.7 | 45 | 41 | 634 | 4.7 | 18 | 35 |

There were high spatial variability in microclimatic conditions recorded in both Finnish and Estonian cow structures. Fig. 4 and 5 show the typical diurnal variability. The results showed that there are diurnal differences in microclimate depending on outside temperature, wind and ventilation rates (Table 2, and Fig. 4 and 5). The ventilation rate was mainly affected by the ventilation opening sizes of the buildings (natural ventilation) which in turn contributed to the microclimate.

The recommended values for microclimate in cow structures were exceeded when the ventilation was inadequate (Table 2, and Fig. 4 and 5). The most eminent problems were related to high moisture content (RH) and freezing of moisture or water during cold weather (Fig. 4 and 5). In some cases, temperatures in the uninsulated cow structures were below the lower critical temperatures (Fig. 4 and 5). In the summer period, there were days when the recorded temperature went above the upper critical temperatures (Fig. 4 and 5). Carbon dioxide concentrations were in the range of the recommended levels in all cases. In some cases, methane concentrations were more than 10 times the recommended levels (table 2). Ammonia emissions were mostly below 10 ppm-vol in both Finnish and Estonian cow structures.

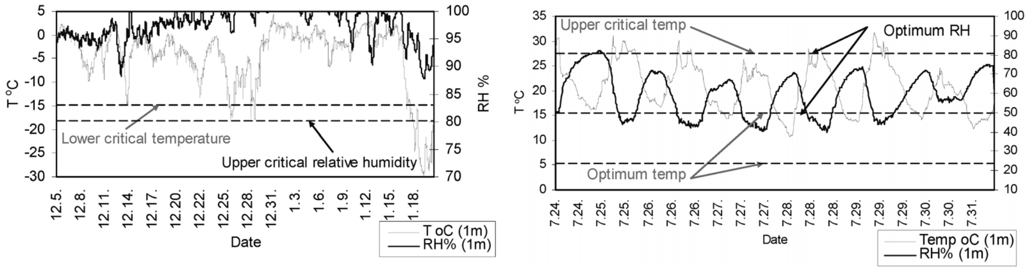


**Figure 4.** Winter (left) and summer (right) microclimatic conditions in a cow structure in Finland

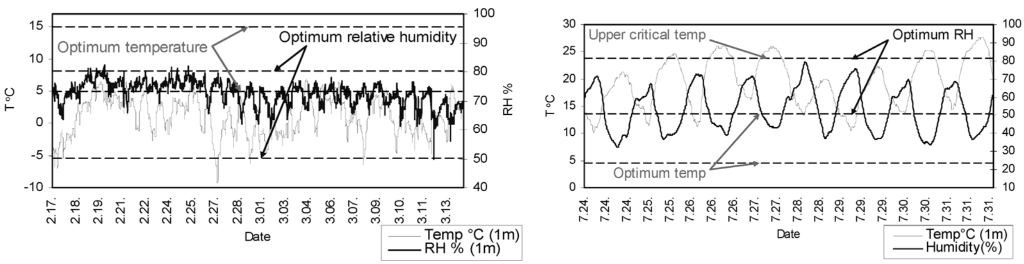


**Figure 5.** Winter (left) and summer (right) microclimatic conditions in a cow structure in Estonia

## CONCLUSIONS

With proper ventilation rate the microclimate can be kept within recommended values. Winter conditions present especially moisture problems and freezing of moisture, water and manure. Normally there was only one or two measured gas or value, which was outside the recommendation.

The basis of the microclimate recommendations were difficult explain, they seemed to be derived mainly from human exposure limits.

## REFERENCES

Amon, T., Boxberger, J. and Alt, C. 2001. Emissions of NH3, N2O and CH4 from dairy cows housed in a farmyard manure tying stall. Nutrient Cycling in Agroecosystems 60:103–113.

Charles, R. 1994. Comparative climatic requirements. In: Livestock Housing (Wathes C M; Charles D R Ed.) pp. 3–24. CAB International.

CIGR, 1984. Climatisation of animal houses. Report of working group. Scottish Farm Building Investigation Unit, Craibstone, Aberdeen, Scotland

Directive 2001/81/Ec. National emission ceilings for atmospheric pollutants. The European Parliament

EVS 839. 2003. Indoor climate. Estonian Centre for Standardisation.

EVS 845. 2004. Building ventilation design. Estonian Centre for Standardisation.

Kivinen, T., Mattila, K., Teye, F., Heikkinen, J. and Heimonen, I. 2006. Functionality of curtainwall ventilation in insulated barns in Finnish climate (Finnish). *Lämpöeristetyn verhoseinäisen lypsykarjapihaton ilmanvaihdon toimivuus*. Agrifood Research Working Papers 119.

Jeppsson, K-H., Gustafsson, G. and Sällvik, K. 2006. "Frostfria stallar" för lösgående mjölkkor (Swedish). Semi-insulated freestall housing for dairy cows. JBT report no. 400

MMM-RMO C2.2, Maatalouden tuotantorakennusten lämpöhuolto ja ilmanvaihto, (Finnish). Heating and ventilation of agricultural production houses. Ministry of Agriculture and Forestry (MMM). Maa- ja metsätalousministeriön rakentamismääräykset ja ohjeet, RMO C 2.2. Helsinki.

MSAH, 2005. Haitalliseksi Todettu Pitoisuus arvot (Finnish). Exposure limits. Sosiaali- ja terveysministeriön oppaita 2005:10. Ministry of Social affairs and Helath (MSAH).

Pajumägi, A. 2007. Uninsulated cowsheds: Ventilation and aspects of building physics. Doctoral thesis, Institute of Forestry and Rural Engineering, Estonia University of Life Sciences.

RTL, 124, 179. 2002. Animal protection law (under Council Directive 98/58/EC). Nõuded vasikate pidamisele ja selleks ettenähtud ruumile või ehitisele. And RT I 2001, 3, 4. Loomakaitseseadus. Riga treaty.

Seedorf, J., Hartung, J., Schroder, M., Linkert, H., Pedersen, S., Takai, H., Johnsen, O., Metz, M., Groot Koerkamp, G., Uenk, H., Phillips, R., Holden, R., Sneath, W., Short, L., White, P., Wathes, M. 1998. Temperature and Moisture Conditions in Livestock Buildings in Northern Europe. J. agric. Engng Res. 70: 49–57.

Zhang, G., Strøm, S., Li, B., Rom, H., Morsing, S., Dahl, P. and Wang, C. 2005. Emission of Ammonia and Other Contaminant Gases from Naturally Ventilated Dairy Cattle Buildings. Biosystems Engineering, 92: 355–364.