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SPATIAL AND TEMPORAL DISTRIBUTION OF TEMPERATURE, RELATIVE HUMIDITY AND AIR VELOCITY IN A PARALLEL MILKING PARLOUR DURING SUMMER PERIOD*

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Abstract

The research aimed at determining the most significant parameters affecting the microclimate of milking parlours, such as temperature, relative humidity and air movement in a parallel milking parlour in real operating conditions. The research was conducted in the summer period, when the risk of heat stress in cattle is higher. To check welfare of cows during milking, days with air temperature >25°C and days with temperature equal or lower than 25°C were analysed. Observation and analysis were performed for air flow in milking parlour, range of supplied air stream and how air movement affects cattle. It was observed that the irregular distribution of air movement led to the development of diverse air velocity in different zones of the milking parlour (0.2–9.0 m·s^{-1}). As a consequence, the conditions inside the barn were not homogenous for all the cattle. A significant effect of the cows and external air temperature (which depends indirectly on orientation of the milking parlour relative to cardinal directions) on temperature increase (approx 6°C) was concluded, with relative air humidity at the level of 85–90%, during the milking, which led to systematic decrease of microclimatic comfort for cattle. Based on the conducted research, it was concluded that the design of ventilation systems in parallel milking parlours should be preceded by increased research not only on ventilation system efficiency but also on the distribution of flow ventilated air.

Key words: welfare, summer, ventilation, air temperature, air humidity, milking parlour

Development of research on optimizing cow welfare conditions has been mainly triggered by the need to increase the profitability of cattle production. New recommendations regarding cattle have obliged breeders to modernize barns or improve the existing milking parlours (Bieda and Herbut, 2007). However, newly established milking parlours are often unsuitably oriented towards cardinal directions, which

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leads to their excessive exposure to sunshine as well as overheating, especially in the summer (Herbut and Angrecka, 2013).

The total time a cow spends in the milking area may vary depending on the number of milking routines per day and the milk yield. The average length of milking is between 8 to 10 minutes and it is conducted 2 or 3 times per day. Time wise, cows spend only a short period of time inside the milking parlour, therefore it is generally assumed that indoor conditions are not significant in terms of cow welfare. According to common presumptions, milking will be successful if the facility is well-ventilated and has been equipped with proper machinery; if a good milking routine has been established; and if the operator works in a proper and comfortable way (Turner and Chastain, 1995; Munksgaard et al., 2001).

Microclimate parameters inside barns and milking parlours mainly depend on efficient ventilation. Cows produce high amounts of heat, steam and carbon dioxide. Additionally, humidity and air pollution levels are also influenced by manure fermentation (Nawalany et al., 2010). Ventilation should ensure an appropriate number of air exchanges per day and an appropriate volume of exchanged air. If it does not work properly, air pollutants (mainly CO_2, H_2S, NH_3) and dust particles negatively influence animal and human welfare (Teye et al., 2008; Herbut and Angrecka, 2014).

However, cows that are milked in the last technological group are already anxious and tired when they enter the milking parlour from the holding area. Sweat production and breathing frequency increase during milking, consequently leading to the increase of inside air temperature and relative air humidity. If the milking parlour is not equipped with an efficient ventilation system, interior thermal and humidity conditions deteriorate with the milking of the next technological groups (Herbut et al., 2012). This reduces cow welfare and may lead to thermal stress (Spiers et al., 2004; Zähner et al., 2004).

In winter, the ventilation system should ensure four full exchanges of air inside the milking parlour per hour. In the summer, this number should range between 40 and 60 exchanges (Broom, 2000). Romaniuk et al. (2005) recommend ventilation efficiency to be 90 $m^3 \cdot h^{-1}$ in winter and 350 to 400 $m^3 \cdot h^{-1}$ in summer.

Ventilation system of the milking parlour should ensure continuous exchange of air so as to avoid excessive temperature and relative humidity increase (Herbut et al., 2012).

Positive pressure ventilation is the most popular ventilation system used in milking parlours. Fans were installed inside walls which supply fresh air to the milking parlour, where the air is mixed creating pressure which pushes out the contaminated air through gravitational outlets usually located on the roof (Gooch and Bickert, 1999).

The aim of the research was to study the variation of microclimatic conditions inside the parallel milking parlour during the summer and their influence on cow welfare. Based on the conducted measurements of temperature and relative air humidity as well as ventilation system efficiency it was possible to establish the parameters affecting the changeability of microclimatic conditions.

Material and methods

The research was conducted in the summer period (June–July) of 2012. The analysed parallel milking parlour was equipped with 2x12 stalls with quick exits and was located on a cattle farm for 470 cows in the village of Nidek (N: 49.9167° E: 19.3333°). The milking parlour was located just next to the holding area.

The building was equipped with a pitched roof at the angle of 17° with four roof windows. The building was built of steel.

The dimensions of the milking parlour were as follows: width: 14.72 m, length: 12.13 m, maximum height – 4.6 m. The building was equipped with positive pressure ventilation system based on four fans produced by Axial Fans (type WO 40/W) with maximum efficiency of 2,800 $m^3 \cdot h^{-1}$ equipped with blinds directing the stream of air downwards. The pairs of fans were located on two opposite walls of the building. The part responsible for air exhaust included three outlet openings, 20 cm in diameter each, located in the roof as well as tilt roof windows. The total efficiency of fans was 11,200 $m^3 \cdot h^{-1}$, that is 155.6 $m^3 \cdot AU^{-1} \cdot h^{-1}$.

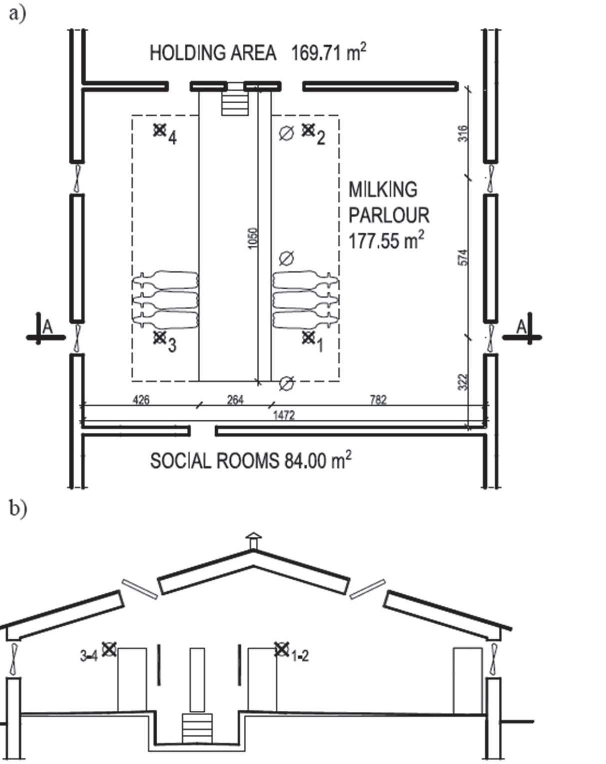

Figure 1. Distribution of measurement points for temperature and relative air humidity inside the milking parlour (1–4): a – projection, b – cross-section A-A

The three technological groups were milked twice a day at the following times: 04:00–8:30 and 16:00–19:30; additionally the cows with the highest milk productivity were milked at 11:00–13:15.

The measurements were conducted with the help of temperature and relative humidity sensors located in 4 measurement points across the milking parlour (Figure 1). The used sensors were Voltcraft sensors DL-120 TH with the measurement range of –40 to 70°C and the accuracy margin of ±1.0°C (–20 to 50°C) for temperature; and the range 0 to 99% RH with the accuracy margin of ±3% for relative humidity.

An additional sensor measuring the parameters of the outside air was located at the farm. All the sensors recorded results automatically every 5 minutes.

The authors also decided to conduct an experiment with smoke generators in order to make observations of main directions of ventilated air movement. The experiment was conducted in conditions equivalent to those during milking sessions, with all fans turned on, closed doors and open roof windows. Smoke generators were distributed at the distance of 2.0 m from the axis of each fan. The course of the experiment was recorded with the help of the video camera. Also, photographs were taken. At the same time, the research team conducted measurements of air velocity inside the milking parlour. The measurements were conducted in points system (interval 0.5 meters in vertical and horizontal) and were repeated in different situations to accurately check the velocity of air flow. These measurements were made with the help of CHY 361 anemometers with the measurement range of 0 to 30 $m \cdot s^{-1}$ and the accuracy of ±3%.

Results

Figure 2 presents results of temperature and relative humidity measurements inside the milking parlour and also outside in the period of 30 June to 20 July 2012. At that time the average air temperature reached 22.6°C and the relative air humidity 66.5%.

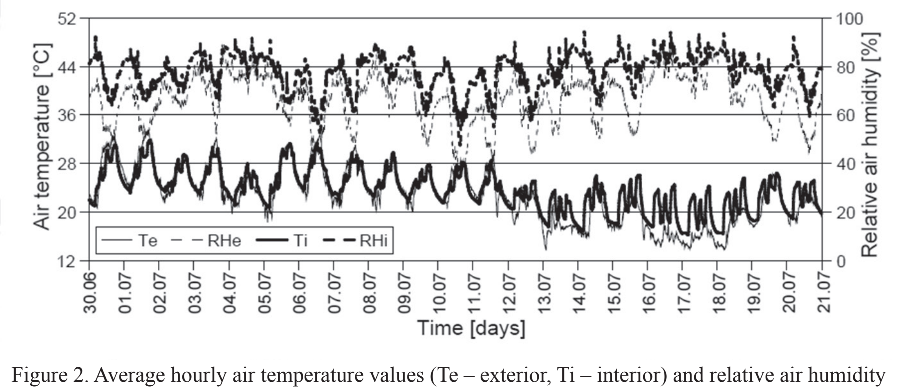

Figure 2. Average hourly air temperature values (Te – exterior, Ti – interior) and relative air humidity (RHe – exterior, RHi – interior) between 30 June and 20 July 2012

The selected period (Figure 2) included some days of high temperatures Te >25°C (30 June–11 July) as well as days when Te was equal or lower than 25°C (12–20 July). The particular days with their temperature data were presented in Figures 3–4.

On 1 July 2012, average outside air temperature was 28.4°C whilst relative humidity was 62.3% (Figure 3).

It was one of the warmest days of the analysed period. The temperature inside the milking parlour was lower by 2 to 3°C, with relative air humidity higher by 10–12% when compared to the outside conditions.

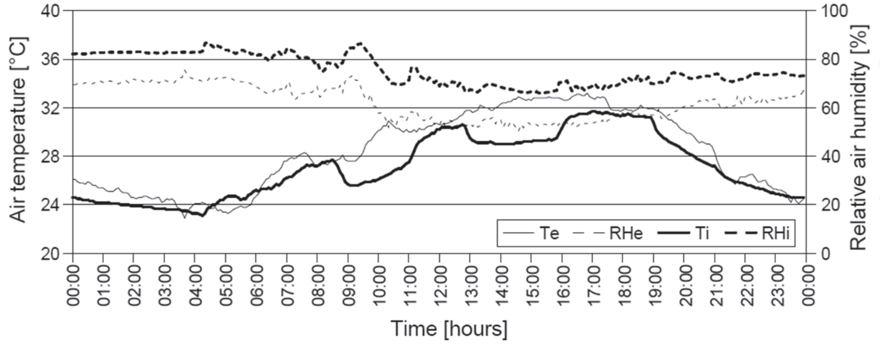

Figure 3. Air temperature values (Te – exterior, Ti – interior) and relative air humidity (RHe – exterior, RHi – interior) on 1 July 2012

With the start of the subsequent milking sessions, the temperature of the air inside the milking parlour increased. The authors observed that the increase of inside temperature during the morning and noon milkings coincided with the changing exposure to sunlight of the building and was approx. 4–5°C. During the afternoon milking session, the temperatures were also higher, yet they remained at the level of approx 33°C.

The moment when the last group of cows from the milking parlour left the building after the morning and noon sessions was linked to air temperature decrease by 1.5–2°C.

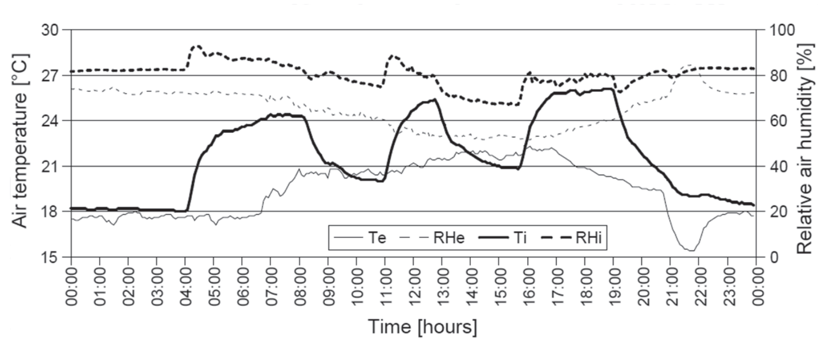

Figure 4. Air temperature values (Te – exterior, Ti – interior) and relative air humidity (RHe – exterior, RHi – interior) on 15 July 2012

On the next day, 15 July 2012, which has been selected for analysis due to different thermal conditions, average temperature of outside air was 19.4°C and relative air humidity was 65.1% (Figure 4).

The moment when the last group of cows from the milking parlour left the building after the morning and noon sessions was linked to air temperature decrease by 4.5–5.0°C.

The spread of smoke trails during the experiment with smoke generators is shown in the projection and cross-sections of the milking parlour, observed at the height of approx. 1.3 m above floor level, that is in the zone occupied by animals (Figure 5).

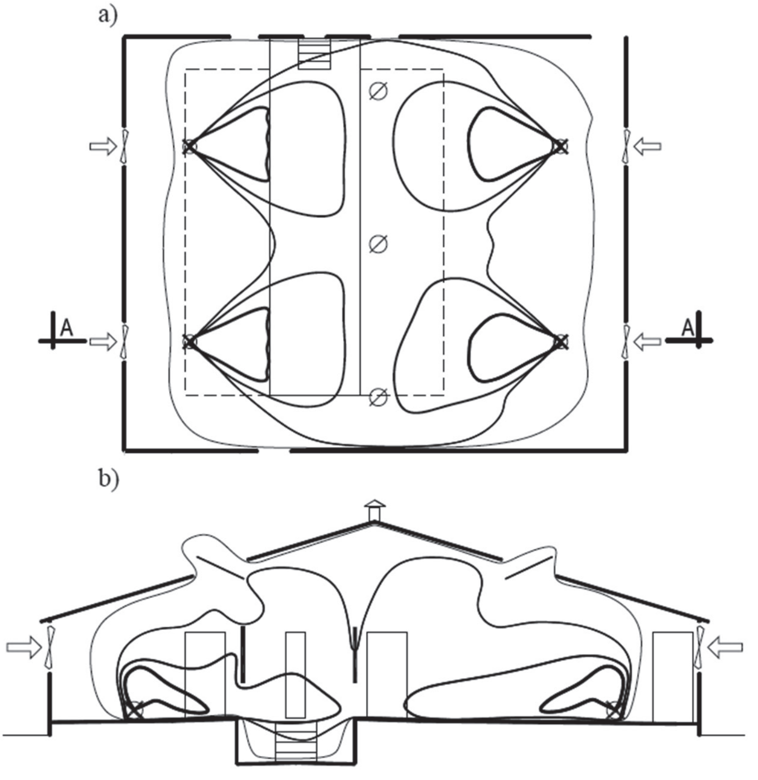

Figure 5. Spread of smoke trails during the experiment with smoke generators, all fans turned on, 30 June 2012

Thickness of the lines depicts the movement of smoke trails in the milking parlour. Thickest lines mark areas in the initial stage of the experiment, the thinner lines indicate the subsequent spread of smoke trails covering wider and wider scope.

The observations of spreading smoke trails have shown that the outlet openings did not work properly – their role was taken over by roof windows, which were open throughout the whole summer period irrespective of weather. Initially, the smoke moved together with the air supplied by the fans. Afterwards, the smoke swirled in the milker's pit and around the milking stalls. Then it got thinner and thinner whilst moving upwards to the roof and left the building through roof windows. The experiment was repeated in the following days, which confirmed the observations presented in Figure 5.

The conducted measurements of air velocity inside the milking parlour made it possible to define different zones of ventilation efficiency (Figure 6).

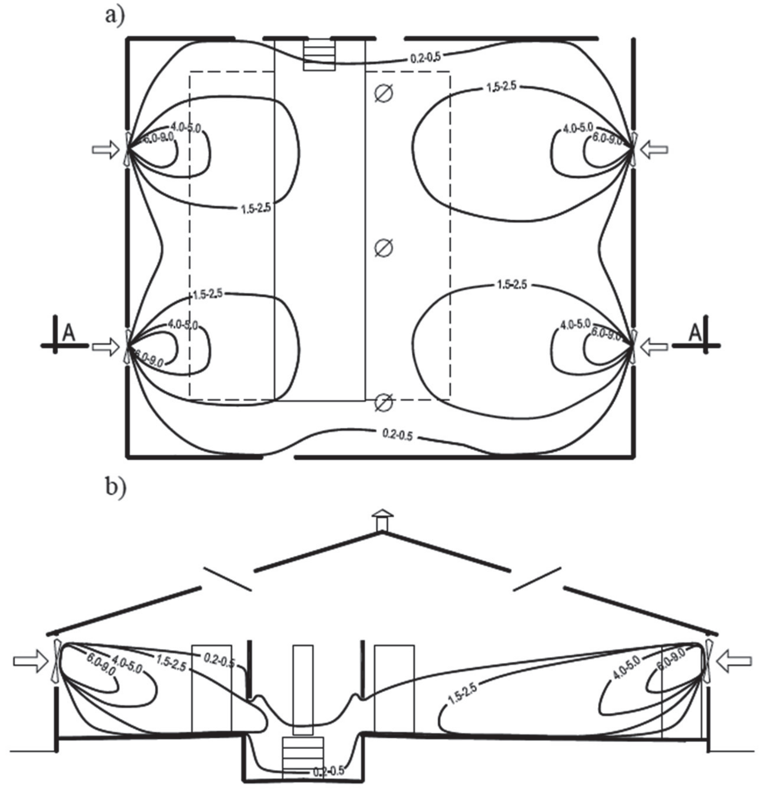

Figure 6. Zones of different air velocities inside the milking parlour (number indicates air velocity in m s^{-1})

Air velocity rate at the distance of 2.0 m from the fans reached the levels of 4.5 m·s^{-1}. Such an air velocity did not pose any threat to the majority of cows in the part of the milking parlour which was adjacent to the return corridor, as the stream of supplied air was directed downwards by the blinds. As a result, the cows waiting at milking stalls were exposed to air movement at the speed of 0.5 m·s^{-1}, and the total speed was at the level of 0.5 m above the floor of the parlour and gradually decreased with height. At the level of cows' heads it was approx. 0.2 m·s^{-1}. Yet, the cows standing opposite the fans were within reach of the air moving at the velocity between 1.5 to 2.5 m·s^{-1}.

In the opposite part of the milking parlour, air movement velocities were most diversified. The heads of cows located closest to the fans were exposed to air moving at the velocity of 4.0–5.0 $m \cdot s^{-1}$. The bodies of these cows and cows located at adjacent stalls were exposed to air moving at 1.5–2.5 $m \cdot s^{-1}$. Air velocities between those zones were definitely lower.

The movement of air was also largely influenced by side barriers installed along the milker's pit. The fans directed the stream of air towards the floor and then it was pushed upwards beneath the barriers. Particular air movement disturbances were observed in that area. It was there that the streams of air supplied by fans located on opposite walls of the building met together. Yet, it is important to note that the fans located closer to the pit had greater impact on air movement in this area.

Discussion

The microclimate of livestock buildings, and in particular free stall barns, has been widely researched with particular focus on its influence on cattle welfare and productivity (Albright and Timmons, 1984; Cook et al., 2005; De Palo et al., 2006; Nawalany, 2012; Herbut and Angrecka, 2013; Strzałkowska et al., 2014). Specialist literature dealing with the issue of dairy cattle welfare defines recommended microclimate conditions for free stall barns. The recommendations are usually limited to the definition of optimal air temperature and relative air humidity, which are regulated with the help of mechanical ventilation systems. For an adult cow, the efficiency of the mechanical ventilation system in the summer period should remain between 350–400 $m^3 \cdot h^{-1} \cdot head^{-1}$ (Romaniuk et al., 2005), and according to Arnold and Veenhuizen (1994) depending on weather, it should be between 60 $m^3 \cdot h^{-1} \cdot head^{-1}$ to approx. 570 $m^3 \cdot h^{-1} \cdot head^{-1}$.

The designers of ventilation systems for milking parlours most often take into consideration the efficiency of fans, which enable the exchange of air appropriate for the given size and population density of the building.

The calculated efficiency of ventilation for the discussed milking parlour seems to be sufficient to ensure cow comfort. However, in the light of conducted experiments, it seems that designing such a ventilation system without taking into consideration the existence of different air velocity zones may have negative influence on cattle welfare. The results of air velocity measurements compared to the recommended values for the summer season of 0.5 $m \cdot s^{-1}$ (Romaniuk et al., 2005) helped to determine areas which were potentially dangerous to cattle due to high speeds of ventilated air, as well as areas which do not fulfil this requirement.

Cattle welfare may temporarily, yet dangerously, decrease if animals stay in an environment where air temperatures exceed the limit value for cows of >25°C and air movement velocity exceeds the norm by even 10 times. Cow welfare is also at risk when the temperature of air increases, yet its velocity is too low.

Therefore, it would seem justifiable to verify whether ventilation systems applied for milking parlours are optimal for these types of buildings. So far, the main criterion has been whether the system is capable of supplying a suitable amount of air inside the building. The choice of fans made on the basis of this criterion may not only be inefficient but also dangerous. Suitable amount of air is supplied inside the milking parlour when the fans work with highest efficiency, which also means that the air stream velocity is at the top value. As a result, we can observe that in some areas of the milking parlour air moves too fast, which is definitely unfavourable to animals, even taking into consideration the fact that they stay in this environment for a short period of time. Values of air temperature and relative air humidity measured during milking of the last technological group compared to the recommended values for cattle (Herbut and Angrecka, 2012) were adverse for welfare of cows. In the researched milking parlour, the temperature of air after the first 24 cows have been milked was approx. 24°C, with relative air humidity remaining at the level of 85–90%, which according to Romaniuk et al. (2005) who recommend maintaining the range of 60-80%, had exceeded the proper values and contributed to the development of heat stress (Dikmen et al., 2008; Silvestre et al., 2009). These parameters gradually deteriorated as subsequent cow groups entered the milking parlour.

In hot days, the fall of temperature values inside the milking parlour after the last technological group has left it was lower when compared to cooler days by 3°C. This was mainly due to lower exposure to solar radiation and also orientation towards cardinal directions. High temperatures of outside air and long exposure of the roof to the sun made it impossible to decrease inside temperatures. The milking parlour was being heated all the time in spite of the fact that the ventilation system was turned on and there were no animals inside. In the case of cooler days, when exposure to sunlight was not that significant, the setting up of fans to maximum efficiency between the milking sessions made it possible to push out the humid and warm air outside of the milking parlour.

Based on the conducted research, it was concluded that the design of ventilation systems in parallel milking parlours should be preceded by increased research not only on ventilation system efficiency but also on the distribution of ventilated air. Efficient ventilation system which is operated properly ensures optimal air parameters and consequently helps to maintain cattle welfare during milking sessions.

Particular attention should be given to the modernized milking parlours. In their case, it is more difficult to plan a symmetric layout of milking stalls and corridors so that the air may circulate without disturbances.

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