HYGIENE EVALUATION OF THE VENTILATION AND HEAT-TECHNICAL QUALITIES OF BUILDINGS USED FOR FREE-BRED DAIRY COWS

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Abstract

A hygienic evaluation of the ventilation and heat-technical qualities was made for three types of buildings used for free-bred dairy cows.

Farmhouse 1 (FH 1) and Farmhouse 3 (FH 3) are semi-open, while Farmhouse 2 (FH 2) is closed. The provided living area for an animal in FH 1 is 8.06 m², in FH 2 - 11.5 m² and in FH 3 - 9.4 m².

It was found that the actual air exchange in FH 1 and FH 3 is insufficient in both - winter and summer. In FH 2, actual air exchange in winter is about 2 times higher than required, while in summer it is also insufficient.

The heat balance in winter for all three buildings is negative. The main reason for negative heath balance in FH 2 is low density of the population. The negative heat balance in FH 1, in both seasons, is a result of the high humidity of the use deep litter.

It was also found that the zero balance (temperature difference) for FH 1 is 0.7°C, for FH 2 - 7.5°C and for FH 3 - 1.6°C.

Key words: hygienic evaluation, ventilation, heat balance, buildings for free-bred dairy cows

INTRODUCTION

The basic requirements for each livestock farm are to create the necessary living conditions of the environment according to the physiological needs of the animals kept in it and to have the technological means to achieve the desired microclimatic factors [5]. The ventilation system has a decisive role in achieving those optimal zoohygienic parameters. A direct marker for evaluating the ventilation is the amount of air that gets in or is removed from the room per unit of time [8]. A number of factors such as outdoor air status, animal productivity, accommodation density, thermostability of the enclosing structures and others determine the air exchange rate [11]. The appropriate air exchange rate for dairy cows weighing between 570 and 800 kg in winter is 2.8 times per hour and 28 times per hour in the summer [2]. The natural ventilation of buildings, supplemented by the use of rotary fans mounted above the row of living cabins and above the feeding paths are able to provide the necessary air speed, assuming they are correctly installed [7].

In order to provide a larger volume of air in the enclosed area and thus the ventilation to be rational, the height of its walls should be 4.3 m and its exposed area should be between 75 and 100% [1]. According to the same authors, a roof with an inclination of less than 18º may cause higher temperatures during the summer and the occurrence of condensation. Petkov and collaborators studies of the microclimate in large herds of cows show that despite the different technological and architectural construction models used, they cannot achieve and maintain an optimal temperature-humidity regime especially during the summer [10].

In the light of the above, we set ourselves the task of making a hygienic evaluation of the ventilation and thermo-technical properties of three types of buildings used for free-bred dairy cows.

MATERIAL AND METHODS

The object of the study were three farms, used for free-bred dairy cows, with different

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capacities, situated in the South-Central Bulgarian region, where the average temperatures during the winter period are in the range of -15°C and in the summer in the range of +32°C.

Farmhouse 1 (FH 1) has a capacity of 67 dairy cows with a total living area of 598.5 m² and a 540 m² area used for walking and rest. The space provided for one animal is 8.06 m². The building is made of brick masonry, it is semi-opened and its dimensions are 45/12 m and a height of 3 m. The length of the short walls is 6 m and the rest 6 m are unclosed. The roof structure is made of galvanized sheet without insulation. The natural ventilation, achieved through the unclosed short walls, matches with the tunnel type. Eight rotary fans (DeLaval) are mounted above the deep litter area, at an angle of 45º, for additional mechanical ventilation. Each one of them has a power of 0.55 kW and a capacity of 60 000 L / h. Four of them are automatically started at temperatures above +18°C and the remaining four are automatically started at temperatures above +25°C.

The feeding is "at will" with an all-purpose fodder mix and constant access to water. The manure is cleaned twice a year, however litter is added periodically. Lighting is natural and its characteristics depend on the season. Artificial lighting is provided by five 100W lamps mounted above the feeding path and three 200W lamps mounted above the walking and rest zones.

Farmhouse 2 (FH 2) has a capacity of 200 dairy cows, grown freely in individual cabins, divided into 4 groups. The total area of the building is 2 310 m² and the space provided for one animal is 11.5 m². The building is made of reinforced concrete and roof panels and its dimensions are 105/22 m. The height of the walls is 4.5 m and the height of the ridge is 5.8 m.

The individual cabins are located on both sides of the longitudinal walls with dimensions 1.10 / 2.10 m. There are no partitions between them. The manure paths are located between the individual cabins and the feeding area.

The floor of the whole building is made of cement. The natural light in the farm is provided by a total of 30 windows, 20 of which are with dimensions 5.80 / 0.90 m and 10 are with dimensions 5.80 / 2.00 m. At the ridge of the building there are also 12 ventilators (windows), each measuring 5.80 / 0.90 m. Artificial lighting is provided by 97 lamps, each consisting of 2 luminary pipes with a power of 40 W. In the winter period, the windows and the ridge ventilators are covered with polyethylene sheets. Mechanical ventilation is provided by 10 ventilators mounted above the walking and feeding areas. Each one of them has a power of 0.55 kW and a capacity of 60 000 L / h.

The manure is cleaned with a delta scraper device that automatically turns on every 3 hours.

Farmhouse 3 (FH 3) has a capacity of 130 dairy cows, grown freely in individual cabins, divided into 2 groups of 65 animals each. The cabins are divided in four rows. The building is an open metal structure with a roof made of thermos panels. The longitudinal walls are made of concrete with a thickness of 0.25 m and a height of 1.5 m. The short walls are 3.0 m in height. The area of the feeding path has no doors and it is fully opened. The total area of the building is 1 248 m², walking area is 595.2 m² and rest area is 422.4 m².The space provided for one animal is 9.4 m².

The building is 48 m long, 26 m wide, 3 m in height to the roof structure and 8 m in height to the ridge. The floor is made of cement. The cabins are covered with a hard rubber mat with a thickness of 2 cm.

Lighting is provided through the opened space of the building with a total area of 170 m². Artificial lighting is provided by 14 luminescent laps, each consisting of 3 luminary pipes with a power of 40 W. Mechanical ventilation is provided by 8 ventilators mounted above the cabins and the walking area, at an angle of 45º. Each one of them has a power of 0.55 kW and a capacity of 60 000 L / h. Four of them are automatically started at temperatures above +18°C and the remaining four are automatically started at temperatures above +25°C.

The manure is cleaned with a delta scraper device that automatically turns on every 6 hours.

The evaluation of the ventilation and thermo-technical properties of the buildings was made according to the accepted methods in the zoohygiene [4] and in the thermo-technics [6].

RESULTS AND DISCUSSION

The role of ventilation is to replace the enriched with gases, moisture, microorganisms and heat air in the buildings with pure atmospheric air. In this way, it maintains not only the microclimate in the buildings for the animal's physiological norms, but also actively participates in the creation of a comfortable environment. In this sense, if we accept the Gooch [2] and Gooch and Timmons [3] conclusions and recommendations for clean air for the animals in a yearlong period, then the buildings we study, according to the number of animals and the height of the sidewalls, should provide the air exchange and air exchange intensity measures indicated in Table 1. They are calculated based on an air exchange rate of 0.47 m^3 / s for a cow. Considering that the air exchange requirements for a cow are the same, regardless of the type of ventilation (tunnel, transverse, longitudinal), the number of fans should also be the same. Moreover, to increase airflow rate at the animal level, additional air exchange capacity should be considered.

Table 1 Required air exchange (m^3 / h) and air exchange intensity (times / hour) of air in buildings

Farm house	Height of side walls, m	Number of cows	Air exchange required (m^3 / h)	Air exchange intensity (times / hour)
FH 1	3	67	113900	2.8/19-28
FH 2	4,5	200	340000	2.8/19-28
FH 3	1,5	130	221000	2.8/19-28

In FH 1 during the cold period of the year, in order to maintain the minimum limit of temperature neutrality (+5°C), the air exchange is about 15 times lower in terms of the released heat and 5 times lower in terms of moisture, although its intensity is kept within the permissible limits - Table 2. This is the reason for the retention of excess moisture in the room in winter, and the retention of heat and moisture in summer.

Table 2 Actual air exchange (m^3 / h) and air exchange intensity (times / hour) of air in buildings

Farm house		To remove excess moisture, m^3 / h	To remove excess heat, m^3/h	Air exchange intensity winter/summer (times / hour)
FH 1	winter	30686	7680	2.6/4.8
	summer	- 497	- 7712	-0.4/-4.8
FH 2	winter	25855	229250	0.3/2.7
	summer	-2596	-23021	-0.03/-0.3
FH 3	winter	17701	-1765	2.6/-2.6
	summer	-1656	-16498	-0.24/-2.4

In FH 2 the opposite is seen - there is over 2 times higher air exchange in the winter (with over 115350 m^3 / h), which pulls the released heat outside, despite the low air exchange intensity (below 1 / h). In the summer, fresh air requirements greatly increase and without the inclusion of additional ventilation capacities, the cost of maintaining homeostasis in the animals will increase as well. This calls into question whether the applied reconstruction of the building was economically viable.

The actual air exchange in FH 3, both for removing excess moisture and for removing excess heat, is extremely inadequate during both seasons. This deficiency is most sensitive in terms of excess heat.

In addition, assuming that the fresh air needed for each cow is 1.700 m³ /h [9] then FH 1 will require an air exchange of 115,000 m³ / h, FH 2 – 340.000 m³ / h and FH 3 – 221.000 m³ / h. However, the actual air exchange is far lower than indicated in Table 2 to keep the target temperature at +5°C in the winter and +15°C in the summer. Increasing the speed of air movement in the animal living area, without affecting their health, would improve the heat exchange between the building and the outside air.

Table 3 Heat gain and loss (kJ/h) in buildings during winter and summer

Farm house	Winter		Summer		Temperature difference (Δt ºC)
	Gain (kJ/h)	Loss (kJ/h)	Gain (kJ/h)	Loss (kJ/h)	
FH 1	313833	858097	270299	623125	+0.7
FH 2	888750	1527924	758798	700615	-7.5
FH 3	610867	746226	526398	140102	-1.6

The heat balance in each of the studied buildings is different (Table 3). We associate this difference with the number of animals kept in them and the differences in their architectural, constructional and technological characteristics. Heat loss in the winter, for all three buildings, is higher than the heat gain. The highest heat loss is measured in the closed building of FH 2 (639 174 kJ / h). According to us the reason for this is the low population density of the animals. The lowest heat loss is measured in the opened building of FH 3 (135359 kJ / h).

In summer the heat balance is almost even in FH 2. Higher heat loss in FH 1, both in winter and in summer, is related to the warming of the deep litter and the release of moisture from it. In FH 3 heat loss is about 4 times lower than heat gain. Excess heat gain causes natural ventilation to be ineffective, even the automatic startup of the rotary fans is insufficient to keep the temperature within reasonable limits.

Using data from the heat balance in the buildings we can determine Δt of the zero balance. It gives us an idea of what outside temperature is required, so that the room temperature will remain at +5ºC. For FH 1, this temperature will be maintained until the outside temperatures drops below +0.7°C, for FH 2 – below -5°C and for FH 3 - below -1.6°C.

CONCLUSION

In conclusion, we can summarize that the ventilation and heat balance in the buildings depends on the number of animals kept in them and the differences in their architectural, constructional and technological characteristics.

The actual air exchange for FH 1 and FH 3 is insufficient in both - winter and summer. In FH 2 the actual air exchange in the winter is about 2 times higher than necessary, while in the summer it is insufficient.

The heat balance in the winter for all three buildings is negative.

The main reason for negative heath balance in FH 2 is low density of the population. The negative heat balance in FH 1, in both seasons, is a result of the high humidity of the deep litter.

The temperature difference of the zero balance in FH 1 is +0.7ºC, in FH 2 is -7.5ºC and in FH 3 is -1.6ºC.

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