Organized natural air exchange in the room for the maintenance of animals

Kaminat Fatullaeva[1*]

[1]Moscow State University of Civil Engineering, Yaroslavskoye highway. 26, Moscow, 129337, Russia

Abstract. The organization of effective ventilation is a key task in the construction and reconstruction of animal housing. Insufficient air exchange in the room leads to the accumulation of harmful gases released by cows: water vapor, methane, nitrogen compounds and carbon dioxide, which causes not only deterioration of animal health, but also increases the heat hazard of premises. The article aims to substantiate the use of natural air exchange in the warm season in agricultural buildings for milk production. The required opening angle of the swing-out flaps of the window openings was determined to achieve a normalized air flow in the animal housing. The option of organizing an additional air flow through the opening of the entrance gate and its effect during the summer period of the year is considered. Studies have shown that the inflow of air through the external gate significantly increases the overall air exchange in the premises for cattle. As a result of the study of the issue, the article presents a method for determining the necessary air exchange for the assimilation of excess heat, moisture and carbon dioxide emissions by animals.

1 Introduction

Livestock buildings are often made of lightweight enclosing structures [1], which simplifies construction and installation work. In the summer, such buildings are considered the most forested, because they serve only as a shelter for livestock with the required internal microclimate. The indoor microclimate is ensured due to properly organized air exchange using natural ventilation – aeration systems [2]. Proper organization of natural air exchange makes it possible to provide the required parameters of the internal microclimate with minimal operating costs compared to other systems [3].

The air exchange should be organized in such a way as to provide favorable conditions for the stay of livestock. The main indicator that impairs appetite, fertility and productivity is heat stress [4, 5, 6]. To reduce the likelihood of thermal stress, great attention is paid to the installation of supply and exhaust vents of the room, their area and location relative to each other. Ventilation should be organized in such a way that air exchange is provided throughout the entire room, without creating stagnant zones.

Studies have shown a shortage of supply and exhaust air (compared with the normalized flow) from the livestock housing in the warm season in the case of opening all the openings

* Corresponding author: kaminat29@mail.ru

of the facades [7]. Since other systems are not provided, the question arises of increasing the area of supply openings along the facades of the building, which can also negatively affect for air exchange in the cold season, leading to an increase in it. In this case, it was decided to take into account the opening of the entrance gates in the air exchange only in the summer period of the year, thus increasing the area of the supply openings [8]. The parameters of the indoor microclimate for animal housing are normalized only for cold and transitional periods of the year [9]. In the case of the warm season, the internal parameters are taken into account through the THI index (THI) [10]. It, in turn, takes into account the temperature and relative humidity of the indoor air in the room when performing calculations.

2 Research methodology

To calculate the natural air exchange, an animal housing building was selected, shown in Figure 1. It is designed to contain 200 animals with holes along the entire length of the walls, which provide air exchange in the room, as well as gates measuring 3x3 m. The gates will also be viewed as supply openings. The hood is organized through the upper part of the building [11]. The distance between the axes of the supply and exhaust ports is 5 m and 7.5 m for the gate. The opening angle of the swing-out windows is 3 degrees ($\mu_{ex} = 0.038$).

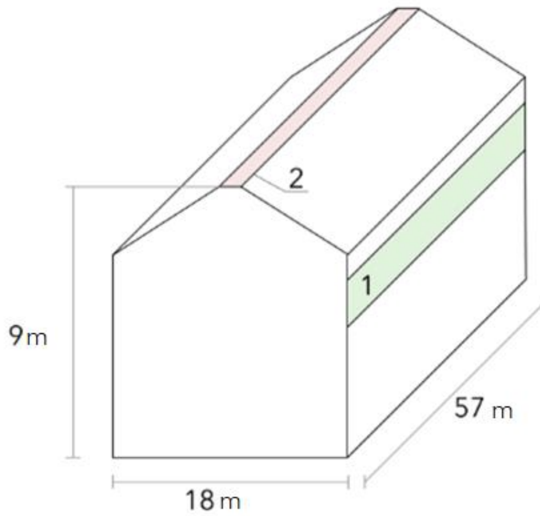

Fig. 1. Lightweight cattle barn for 200 heads: 1 – intake ventilation opening; 2 – exhaust ventilated light ridge.

The calculation was performed for two variants:

1. air enters the room through the swing-out window sashes at an angle of 3.5 degrees;
2. air enters the room through the swing-out windows and open gates with the same opening angle.

Parameters of the outdoor microclimate [12]:

• temperature $t_{out}^{0,95} = 20\ °C$;

• the maximum of the average speeds in points for July $v = 3,1 m/s$.

Figure 2 shows the average values of temperature and velocity for the summer period of the year (3 months) during the selected period of time.

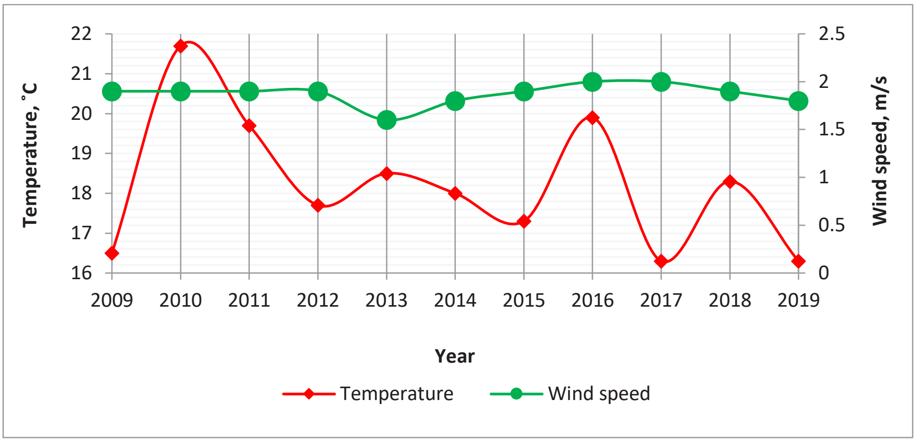

Fig. 2. Average outdoor air temperatures and wind speeds in the summer period according to the data of the weather station.

The ratio of available pressures for supply and exhaust ports, which in total are equal to the calculated pressure difference, is defined as (1):

$$T = \frac{\Delta P_{sup}}{\Delta P_{ex}} = \left(\frac{\mu_{ex} A_{ex}}{\mu_{sup} A_{sup}}\right)^2 \cdot \frac{\rho_{ex}}{\rho_{sup}} \tag{1}$$

If the air flow through the open gate is taken into account, then (2):

$$\Delta P_{\text{sup}} = \frac{T}{1+T}\left(\Delta P_{ex.v} + \Delta P_{op.g}\right) \tag{2}$$

The available pressure for the exhaust vents (3) determines this way:

$$\Delta P_{ex} = \Delta P_{ex.v} + \Delta P_{op.g} - \Delta P_{\text{sup}} \tag{3}$$

Total supply air consumption (4):

$$G_{\text{sup}} = \sqrt{\Delta P_{\text{sup}}}\left(3600 \mu_{\text{sup}} A_{\text{sup}} \sqrt{2\rho_{out}} + 3600 \mu_{op.g} A_{op.g} \sqrt{2\rho_{out}}\right) \tag{4}$$

For exhaust (5):

$$G_{\text{sup}} = 3600 \mu_{ex} A_{ex} \sqrt{2\Delta P_{ex} \cdot \rho_{ex}} \tag{5}$$

Let's consider the calculation of air exchange taking into account excess heat, moisture release and carbon dioxide intake from animals. The TVI index for the selected parameters of the internal microclimate (t_{air} = 23 ºC and φ_{air} = 75 %) (6) [9]:

$$THI = t_{air} + 0{,}36 \cdot t_p + 41{,}2, \tag{6}$$

where t_p is the dew point temperature, °C.

The threshold of thermal stress of animals occurs at THI = 75.

To determine the air exchange, it was assumed that the animal housing was designed for five hundred heads. To calculate the apparent heat, water vapor and carbon dioxide, it is necessary to know the lactation level, which is equal to 15 liters /day for the number of animals chosen by us. Then the apparent heat gain Q^h_{gain} is 92 kW, water vapor W is 105 kg/h, and carbon dioxide M_{co_2} is 28,000 l/h. The heat and humidity ratio ε is 5690 kJ/kg.

The required mass air consumption for the assimilation of excess heat from animals, harmful emissions (carbon dioxide) and moisture:

$$G^{T}_{a.\mathrm{sup.}} = G^{T}_{a.ex.} = \frac{3{,}6 \cdot Q^{h}_{gain}}{c\,(\,t_{rem} - t_{out}\,)}, \quad \text{kg/h} \tag{7}$$

$$G^{co_2}_{a.\mathrm{sup.}} = G^{co_2}_{a.ex.} = \frac{1000 \cdot M_{co_2} \cdot \rho_{co_2}}{C_{ex.h.} - C_o}, \ \text{kg/h} \tag{8}$$

$$G^{W}_{a.\mathrm{sup}} = G^{W}_{a.ex.} = \frac{W}{d_{rem} - d_{out}}, \text{kg/h} \tag{9}$$

We compare the maximum air consumption with the requirements of zoohygienic standards [8] (18,000 kg/h for the room in question). We calculate the actual air flow through the aeration openings with varying degrees of flap opening according to the method described above.

3 The results of the study

Analyzing the results obtained (Figure 3), the following conclusions can be drawn. The required air consumption for the assimilation of excess heat from animals significantly exceeds the normalized, calculated according to zoohygienic standards, while the air consumption for the assimilation of carbon dioxide and moisture intake is not enough to ensure the minimum necessary air exchange. Thus, the calculated flow rate according to zoohygienic standards is taken as the calculated one when choosing the area of the supply and exhaust openings (the angle of opening the flaps).

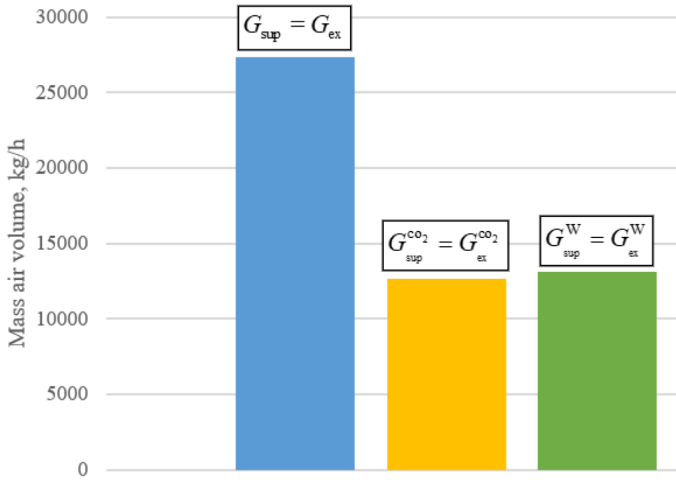

Fig. 3. Air exchange rates for the assimilation of excess heat, moisture, and carbon dioxide emissions from animals.

With the parameters of the outdoor air $t^{0,95}_{out} = 20\ °C$ and, the air flow rate $v = 3,1 m/s$ with the inflow through the gate was 27260 kg/h, the air flow rate using slit ventilation was 13650 kg/h. At average values of temperature and wind speed, the calculation results of which are shown in Figure 2, we calculate the air exchange for two options: with an inflow only through openings along the facades of the building and with an additional inflow through the open entrance gate. The result showed insufficient air consumption during slit ventilation in the warm season compared with the normalized indoor air exchange (Figure 4).

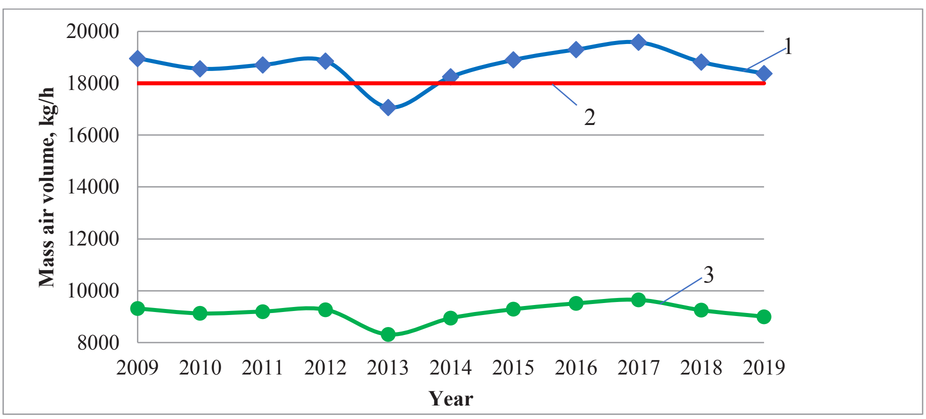

Fig. 4. Results of aeration calculations in the warm period of the year: 1 – supply air flow through the gate, kg/h; 2 – normative air exchange, kg/h; 3 - air flow without gate (slotted ventilation), kg/h.

Analyzing the graph, we can say that the opening of the gate contributes to an increase in air exchange almost twice. However, one should not forget that air exchange is carried out due to natural forces, and such a parameter as wind speed has a great influence on its magnitude, which we observe on the graph for 2013, when the value of air exchange fell below the zoohygienic norm due to a decrease in wind velocity, which is unacceptable [8].

To determine the ratio of the volume of air entering through the swing-out windows to the air exchange through the gate, a calculation was performed with the openings fully open. The ratio was 60% to 40%, where a larger volume of air penetrates through the hinged sashes of the windows.

The results of the calculation of air exchange during the entire summer period are presented above, but the task of aeration is to ensure air exchange not lower than the normalized one every day. Therefore, to assess the daily air exchange in the room, calculations were performed for each hour of the selected day at different angles of opening of the swing-out windows. To ensure an air flow rate not lower than the flow rate according to zoohygienic standards, it is possible when opening aeration openings by more than five degrees (Table 1). At lower values, the air flow is not sufficient to meet the zoohygienic requirements. A significantly larger opening angle of the flaps can lead to an increase in air exchange and, accordingly, to a change in the parameters of the internal microclimate.

Table 1. Calculation results for the angle of opening of the sash from 2 to 5 degrees

Time	Air consumption, 10^3 kg/h, at the angle of opening of the window sash:					Air consumption according to zoohygienic standards, 10^3 kg/h
	2	2,5	3	3,5	5	18
0	7.898	9.693	11.490	13.640	19.390	18
1	7.945	9.751	11.560	13.720	19.500	18
2	7.975	9.788	11.600	13.780	19.580	18
3	7.984	9.799	11.610	13.790	19.600	18
4	7.975	9.788	11.600	13.780	19.580	18
5	7.945	9.751	11.560	13.720	19.500	18
6	7.898	9.693	11.490	13.640	19.390	18
7	7.836	9.617	11.400	13.530	19.230	18
8	7.767	9.532	11.300	13.420	19.060	18
9	7.693	9441	11.190	13.290	18.880	18
10	7.621	9.353	11.080	13.160	18.710	18
11	7.555	9.272	10.990	13.050	18.540	18
12	7.499	9.203	10.910	12.950	18.410	18
13	7.456	9.151	10.850	12.880	18.300	18
14	7.430	9.118	10.810	12.830	18.240	18
15	7.422	9.109	10.800	12.820	18.220	18
16	7.430	9.118	10.810	12.830	18.240	18
17	7.456	9.151	10.850	12.880	18.300	18
18	7.499	9.203	10.910	12.950	18.410	18
19	7.555	9.272	10.990	13.050	18.540	18
20	7.621	9.353	11.080	13.160	18.710	18
21	7.693	9.441	11.190	13.290	18.880	18
22	7.767	9.532	11.300	13.420	19.060	18
23	7.836	9.617	11.400	13.530	19.230	18

4 Discussion

The organization of natural air exchange in such premises as cowsheds is a reasonable cost-effective solution compared to the use of mechanical ventilation, which is an alternative solution for the warm season. Achieving an air exchange not lower than the normalized one in the event of changes in climatic conditions, such as a decrease in wind speed, is possible with the help of additional natural air exchange through the gate. In addition, the quality of the indoor microclimate also depends on ensuring a normalized air exchange. The greater the air exchange, the lower the amount of carbon dioxide [15].

5 Conclusion

Based on the results obtained in the study, the following conclusions can be drawn:

- additional air exchange through the gate increases it to normalized values at temperatures and wind speeds unfavorable for natural air exchange;
- in the warm season, it is necessary to fully open the swing-out window flaps to ensure air exchange in the volume of the entire room for animal husbandry.

References

1. V.A. Medvedsky, A.S. Dogel, Animal husbandry of Russia. **4.** 19-21 (2016)
2. M.V., Bodrov Yu.Ya. Kuvshinov, Bulletin of MGSU **2.** 234-238 (2011)
3. D.V. Abramkina *Natural ionization of premises* Proceedings of the XX International Interuniversity scientific and practical conference of students, undergraduates, postgraduates and young scientists. pp. 911-917 (2017)
4. N.P. Buryakov, Buryakova M.A., D.E. Alyoshin, Russian Veterinary Journal. Farm animals **3.** 5-13 (2016)
5. V.A. Medvedsky, A.S. Dogel, Actual problems of intensive development of livestock breeding **19**. 222-227 (2016)
6. A.S. Dogel, V.A. Medvedsky, Actual problems of intensive development of animal husbandry **19(2).** 222-227 (2016)
7. B. Khodanovich, Livestock breeding of Russia **2.** 37-39 (2011)
8. N.N. Novikov, Vestnik VNIIMZH **4 (4).** 34-42 (2011)
9. RD-APK 1.10.01.03-12 Methodological recommendations for the technological design of cattle farms of peasant (farm) farms (M.: FSBI "Rosinformagrotech", 2012)
10. V.F. Vtoriy, V.V. Gordeev, et.al., Vestnik VNIIMZH **4 (24).** 67-72 (2016)
11. N.N. Novikov, Vestnik VNIIMZH **4 (4).** 34-42 (2011)
12. A.M. Bortnikov, B.L. Maravin, *Nomogram for determining air exchange and micro–climate parameters in cowsheds during the cold season* In the collection: Ways to increase the resistance of agricultural animals.Collection of works. Federal State Budgetary Budgetary Institution "All-Russian Scientific Research Institute of Computer Science". pp. 131-137 (1985)
13. V.F. Vtoriy, S.V. Vtoriy, E.O. Lantsova, Dairy bulletin **4(24).** 72-79 (2016)
14. I.M. Kvashnin, I.I. Gurin, AVOK **5.** 34-41 (2008)
15. H.J. Müller, B. Möller, Application of natural ventilation in cattle barns, Proceedings of Clima 2007. Well being indoors [Electronic resource]. (2007)